THE HAWAIIAN PLANTERS' RECORD

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An International Conference of Cane Sugar Men

Meeting as the sugar section of the First Pan-Pacific Food Conservation Conference, representatives from various parts of the cane sugar world held discussions on technical problems of common interest, July 28 to August 14, 1924.

There were thirteen sessions in all. The subjects which received attention are listed as follows, with the names of those presiding as leaders of the discussions:

July 29—Sugar Cane Breeding (continued August 5), E. W. Brandes.
July 30—Sugar Cane Quarantine, H. L. Lyon.
August 1—Methods of Cultivation, Hunter Freeman.
August 4—Varieties and the Jeswiet Identification System, Mario Calvino.
August 5—Cane Diseases, D. S. North.
August 6—Bud Selection, H. F. Clarke.
August 6—Cane Entomology, O. H. Swezey.
August 7—Soils and Fertilizers, Kintaro Oshima and G. R. Stewart.
August 8—Rodent Control, C. E. Pemberton.
August 11—Factory Engineering, Norman Kay.
August 11—Factory Operation and Control in Sugar Cane Factories, W. R. McAllep.

August 13—Irrigation, Wm. P. Alexander.

Those who participated in the discussions, listed by countries, were:

Australia—

M. S. Barnett, Head of Technical Field Section, Colonial Sugar Refining Company.
Hunter Freeman, Field Officer, Colonial Sugar Refining Company.
D. S. North, Plant Pathologist, Colonial Sugar Refining Company.

Continental United States—

E. W. Brandes, Pathologist in Charge, Sugar Plant Investigations, U. S. D. A.
T. D. A. Cockerell, Professor of Zoology, University of Colorado.
C. L. Marlatt, Chairman, Federal Horticultural Board, U. S. D. A.
Herbert Osborn, Research Professor, Ohio State University.

Cuba—

Mario Calvino, Director, Experiment Station of Chaparra Sugar Company.
Ralph Wood, Manager, Chaparra Sugar Company.

Fiji—

Harry Flockton Clarke, In Charge Agri. Experiments, Colonial Sugar Refining Company.

Formosa—

Migaku Ishida, Chief of Sugar Exp. Sta., Government Research Institute.
Kintaro Oshima, Director, Dept. Agr., Government Research Institute.

India—

(R. L. Pendleton, formerly of India, now with University of Philippines.)

Mexico—

R. H. Van Zwaluwenburg, Entomologist, United Sugar Companies.

Philippine Islands—

(H. Atherton Lee, formerly of the Philippines, now with H. S. P. A. Experiment Station.)
R. L. Pendleton.

Porto Rico—

Norman Kay, Chief Engineer, Central Aguirre Sugar Company.

Hawaiian Islands, U. S. A.—

H. P. Agee
W. P. Alexander
J. D. Bond
W. van H. Duker
C. F. Eckart
W. G. Hall
R. H. Hughes
Horace Johnson
Ernest Kopke
Y. Kutsunai
H. Atherton Lee
H. L. Lyon
W. R. McAllep
W. L. McCleery
W. W. G. Moir
S. S. Peck
C. E. Pemberton
J. Lewis Renton
Twigg Smith
Walter E. Smith
J. B. Steffee
G. R. Stewart
O. H. Swezey
J. A. Verret
J. W. Waldron
John M. Watt
F. X. Williams
J. N. S. Williams

Notes from the International Conference

Factory Operations (By W. R. McAllep)

On Monday, August 11, the program of the sugar section of the Pan-Pacific Food Conservation Conference was given over to discussing factory operations. In the morning Mr. Norman Kay, Chief Engineer of Central Aguirre, Porto Rico, led the discussion from an engineering standpoint. In the afternoon session technical considerations and chemical control were taken up with W. R. McAllep leading the discussion.

Mr. Kay gave an interesting talk on grooving with particular reference to handling returned settlings from the Petree process. The problem was solved by replacing the customary 60° grooving with grooving of 37½° angle and ½ inch pitch. The extraction was higher than before the Petree process was installed but moisture in bagasse was in excess of 50 per cent.

Mr. Ralph Wood, administrator of the Chaparra estate of the Cuban-American Company, spoke of milling under Cuban conditions. On account of an ample supply of cheap cane and a limited grinding season, extraction is considered secondary to capacity. Double crushers with 60° grooving, 3-inch pitch on the first and 1.5-inch pitch on the second, together with comparatively coarse grooving on the following units, have been found the best solution of this problem of passing a large tonnage of cane through the mill.

Mr. Barnett, of the Colonial Sugar Refining Company, spoke of milling practice in Fiji and Australia. The type of shredder (known in Hawaii as the National) is used in many mills. Extraction is obtained by a combination of milling and diffusion. In some factories long maceration baths, similar to those at McBryde Sugar Company are used. In other factories large annular drums containing revolving rakes are installed between the mills. In both cases the apparatus is kept partly filled with maceration water. The partly crushed cane averages about fifteen minutes in passing through them. The maceration baths are kept hot to prevent bacterial action and lime is added to reduce inversion.

Mr. Duker spoke on the importance of having Krajewski crusher rolls mesh properly.

Under the subject of milling practice in Hawaii, Mr. Hall spoke on the advantages of the Searby shredder.

Discussion centered largely on efforts during the last few years to improve mill sanitation, including replacing the old slat conveyors with the Ewart, Ramsey, and Meinecke types, the installation of juice pans with steep sides under the mills, the use of antiseptics around the mill and efforts to overcome the objectionable features and deficiencies of the conventional type of juice strainer, including returning the juices used as maceration without straining, the type of pump used for this purpose and the Peck strainer.

Mr. Kopke discussed centrifugal separation applied to handling settlings and other factory problems.

The afternoon session was opened by outlining the work of the Sugar Technology Department of the Experiment Station of the H. S. P. A.

Under the subject of clarification, Dr. Ishida stated that 8 of the 45 factories in Formosa made white sugar for direct consumption, using the carbonatation process. Dr. Ishida also described the clarification process for use in direct consumption sugar manufacture developed by him at the Formosa Experiment Station. Ammonium and magnesium acetates are used. The increase in purity is as much as 7 or 8 points. The process has been tried out on a factory scale but is not yet used commercially. Filtration was one of the principal difficulties encountered.

The general discussion of clarification included the work in recent years at the H. S. P. A. Station, the Petree process and Dr. Horne's process. Under the discussion of the Petree process it was pointed out that while increases in extraction have been secured after installing it in cases where extraction is comparatively low, in Hawaii with high extractions a loss in extraction has followed its installation. The danger of inversion during the lengthened settling time was also pointed out. Favorable results in clarification were attributed more to the efficiency of the Dorr clarifier than to the process itself.

In the discussion of Dr. Horne's process, it was brought out that juices are first limed, heated and settled. Sodium phosphate is then added, replacing lime salts with the more soluble sodium salts, after which the juice is resettled. This has interesting possibilities in the way of reducing scale in evaporating apparatus and in reducing ash in the sugar. It is certain that most excellent clarification can be secured in any juices with this process.

During the discussion of refining qualities of sugar the fact was brought out that the Colonial Sugar Refining Company, which refines its own raws, produces sugars of 98.5 or higher polarization. The average polarization in Cuba was stated to be about 96.5.

Determining the amount of sugar entering the mill on the cane carrier was the principal subject discussed under Chemical Control. No satisfactory method has been developed for determining this directly. In Java, the Philippines, Formosa and Cuba it is calculated in approximately the same manner as in Hawaii; that is, sugar in bagasse is added to sugar in the mixed juice, and the sum accepted as the sugar in the cane, undetermined losses at the mill being disregarded. In Fiji and Australia sugar in the cane is calculated from the first expressed juice analysis using the following formula:

s = % sucrose in juice from front roller of first set;
f = % fibre in cane;

then,

$$\%\ \text{sucrose in cane} = \frac{s \times (100 - (f + 5))}{100}$$

Efficiencies of different mills are compared on the basis of the ratio of a factor termed "Pure Obtainable Cane Sugar" to the sugar recovery in the bags. The factor "Pure Obtainable Cane Sugar" is calculated as follows:

s = (same as above)
f = (same as above)
S = % sucrose in cane (as above)
b = brix of juice from front roller of first set

then,

$$B = \text{Brix of cane} = \frac{b \times (100 - (f + 3))}{100}$$

and

$$\text{P. O. C. S. in Cane} = S - \tfrac{1}{2}(B - S)$$

In Cuba, boiling house efficiencies are calculated on the basis of Winter's formula. The quality ratio table formerly used in Hawaii is the reciprocal of the value obtained by this formula.

After a discussion of the difficulty in understanding manufacturing data reported from different countries and the desirability of having a uniform basis, the following resolution was adopted:

Be it Resolved, That in view of the difficulty in interpreting the figures obtained in the chemical control exercised in the sugar industry, it is desirable to adopt a uniform system of reporting data obtained in the manufacture of cane sugar, to the end that figures reported in one country may be understood in every other cane-producing region.

Sugar Cane Diseases (By H. Atherton Lee)

Root-rot was the opening subject of the discussion on cane diseases at which Mr. D. S. North, of Australia, presided.

The root-rot of Louisiana was described by Dr. E. W. Brandes of the U. S. Department of Agriculture, Washington, D. C. He stated that R. D. Rands, also of the Department of Agriculture, had found the cause of the root trouble in Louisiana. Dr. Brandes mentioned that he recently visited fields of some of the plantations here on Oahu, and, on Lahaina cane at Ewa Plantation, had found an organism similar to the causal organism of root-rot in Louisiana. A cable had just been received from Dr. K. F. Kellerman of the Department in Washington permitting the release of information, then in press, purporting to establish the cause of root-rot of sugar cane in Louisiana.

Dr. Brandes proceeded to say that in Louisiana small holes were found upon the roots, resulting in the root destruction, and that Mr. Rands had shown that a small mollusc or snail of the genus *Zonitoides* was responsible for these holes. A description of the holes was given.

Mr. Otto H. Swezey immediately brought out the point that investigators in Hawaii were familiar with these snail punctures, and he had mentioned four species of these molluscs in one of the publications of the Experiment Station, several years previously. He stated his view, however, that the work of the molluscs could not be considered responsible for what is called Lahaina disease here in Hawaii.

Mr. H. Atherton Lee pointed out that the injuries resulting from molluscs were not alone associated with root-rot of Lahaina cane; but that some of the healthiest Lahaina cane, as well as Yellow Caledonia, D 1135, and H 109 would often show attacks of the molluscs. Cane affected with these mollusc holes of the roots did not in many instances evidence any indication of Lahaina disease.

Dr. Harold Lyon brought out the same point and also stated that Mr. Cyril E. Pemberton had shown that in addition to the molluscs, a centipede would cause similar holes on cane roots. Mr. Pemberton mentioned the facts leading to the finding of the relationship between the holes and the centipedes. Many of the holes were smaller than those caused by molluscs and were too small to be

accounted for in that way. A study of the problem had therefore been made, and centipedes definitely associated with these very small holes.

Returning to the question of the relationship between the molluscs and Lahaina disease it was brought out that the collection of these molluscs was made by Dr. Brandes from the field at Ewa in which Mr. W. T. McGeorge had shown the high salt concentration. Mr. McGeorge had subsequently shown rather clearly in culture studies that the Lahaina trouble in this field was due to this high salt concentration.

Under these circumstances the injuries resulting from the molluscs were apparently secondary, or at least a minor factor in causing the trouble. Mr. W. P. Alexander, of Ewa Plantation, described the area in which the molluscs had been found and corroborated the statements concerning the high salt concentration of the area.

Dr. Lyon pointed out that there were a number of root troubles; that Lahaina disease which was at one time considered to be due to a single cause had now resolved itself into at least three distinct troubles. He stated that the matter of the molluscs would no doubt be gone into thoroughly.

Mr. Guy R. Stewart related the methods of attack on Lahaina disease by the soil investigators. In several instances salt concentration had been shown by Mr. McGeorge to be high enough to be responsible for what was called Lahaina disease. In another district high acidity with a high concentration of soluble aluminum salts were held responsible for what had also been called Lahaina disease.

Two root diseases of cane were known in Formosa, according to Dr. Migaku Ishida, but he stated that not much progress had been made concerning their nature. In Australia, according to Mr. D. S. North, a root disease occurs which is one of their serious troubles. He related experiments in which they were able to transmit the root disease by butt cuttings. There are apparently several types of root troubles in Australia, according to Mr. North.

Mr. North then pointed out the need for knowledge of cane diseases in the various cane countries; with such knowledge, spread of such diseases to new countries could then be easily prevented. The more serious cane diseases of Australia were listed as follows: Gum disease caused by *Bacterium vascularum;* leaf-scald caused by a bacterial organism not yet published upon; Fiji disease, the cause of which is unknown; mosaic disease, the cause of which is also unknown; downy mildew caused by a fungus, *Sclerospora sacchari;* red-rot; various root rots; rust caused by the fungus *Puccinia kuehnii;* top rot; leaf sheath rots probably caused by *Rhizoctonia* and *Sclerotium* species; and knife cut.

Mr. North asked Mr. Lee to list the cane diseases of Hawaii and also of the Philippines.

The Hawaiian Islands were stated by Mr. Lee to be rather fortunate, in their comparative freedom from serious cane diseases. Although many planters in Hawaii felt that all cane diseases were present in Hawaii, compared with Australia, Java, India, Formosa or the Philippines this country is fairly free of cane diseases. The diseases here in order of the losses caused at the present time would probably be as follows: Mosaic disease, Lahaina disease, red stripe, eye-

spot, Pahala blight, iliau, sectional chlorosis, ring-spot, pineapple disease of standing cane and leaf-freckle. Red-rot has been recorded in Hawaii only once; a leaf-spot caused by a fungus of the genus *Phyllosticta* was also observed once or twice. Of these diseases, mosaic disease causes little or no loss on most plantations, although on a few plantations attention is necessary to prevent material losses which are now occurring. The other diseases are causing very slight losses throughout the Territory at the present time.

In the Philippines, the following diseases are known: Fiji disease, leaf-scald, cane smut, mosaic disease, downy mildew, eye-spot, a flowering parasite somewhat similar to the mistletoe that lowers the qualtiy of the cane juices enormously, ring-spot, red-rot, pineapple disease of cuttings and of standing canes, pokkah bong, sclerotial banded disease, a leaf-spot caused by the fungus *Cercospora kopkei,* another spot caused by a fungus of the genus *Pestalozzia,* another leaf-spot caused by a fungus, *Phyllachora sacchari,* rust caused by the fungus *Puccinia kuehnii,* sooty mould, sheath-spot caused by the fungus *Bakerophoma sacchari,* wilt caused by the fungus *Cephalosporium sacchari,* and leaf-freckle, the cause of which is unknown.

The fundamental policy in cane disease control for the Hawaiian Islands, according to Mr. Lee, was to exclude those diseases occurring in other countries which had not yet reached this country. Control of most of these foreign diseases could be effected but it would cost money and it would be much cheaper to exclude the diseases than to combat them once they became established here.

Dr. Ishida listed the diseases known in Formosa, mentioning especially mosaic disease, red-rot, pineapple disease, two kinds of root disease, and many other troubles which are in the course of investigation.

In Cuba, Dr. Mario Calvino, of Central Chaparra, mentioned mosaic disease and a trouble which he called blight.

The question of the importation of cane diseases on bamboo poles, or leaves used as packing material, was raised by Mr. E. M. Ehrhorn, Chief of the Plant Inspection Service in Hawaii. It was agreed by the delegates that such importations were a possible source for the admittance of organisms, possibly of minor importance on bamboo, but under certain climatic conditions or on certain varieties might be serious on cane. It was the consensus of opinion that the matter should be looked into more fully.

Gumming diseases were next discussed by Mr. North. Gum disease in Java was distinct from gumming disease in Australia, but was very similar to leaf-scald which occurs in Australia. Leaf-scald is characterized by leaf streaks which afford the chief symptom for identification.

These streaks become visible as soon as the leaf unfolds and turns green. The larger ones may even be faintly discerned in white immature leaves unfolded by hand. They occur either on the midrib or on any part of the leaf blade or leaf sheath. Some of them traverse the whole length of the leaf. As they strictly follow the course of the vascular bundles, those located on one side run out on the leaf margin at the top end. But the smaller ones instead of traversing the whole length may fade away after running a certain length. They are straight, well defined, narrow, even streaks, creamy, almost pure white in color.

They persist as long as the leaf remains green, but with age they tend to broaden out and become diffused, afterwards withering; this process usually commences towards the leaf tip and works downward. Reddish spots or blotches may also appear on them. Numerous bacteria are found in these streaks in microscopic sections, located in the xylem elements of the vascular bundles.

In the stem, numerous reddened vascular bundles are to be found, more especially in the nodes. They even occur in the embryonic tissues almost up to the growing point. Shooting of the eyes is most pronounced, even the immature eyes near the growing point usually showing a tendency to shoot. The side shoots display symptoms (leaf streaks, etc.) analagous to those of the main stem. They are particularly valuable for identification purposes in more mature canes, because leaf streaks can often be found on them, when they have been obscured by withering on the leaves of the main stem.

Mr. North also described the leaf streaks of gumming disease. The streaks are not present as a rule when a leaf first unfolds, but they develop in the mature leaves, thus being found chiefly on the older leaves. They occur most commonly towards the leaf tips, but may occur on any part of the leaf blade. In color they are yellow and marked with tiny reddish brown spots. They are fairly straight but have irregular margins and do not so strictly follow the course of the vascular bundles as the leaf-scald streaks do. They keep on growing in length, the older portions withering and the leaf tending to split. Typically, the withered portions occur towards the leaf tip, but often streaks consist of a central withered portion, with a live yellow portion at each extremity. In rare cases, streaks are found present when a leaf unfolds and turns green, then having every appearance of having travelled up from the stalk below. These streaks sometimes closely resemble those due to leaf scald of the broader spreading type, especially if, as sometimes occurs, they are devoid of the brown spots and run the whole length of the leaf.

Dr. Lyon again emphasized the need for keeping leaf scald and gumming disease out of Hawaii, since he believed these diseases would be very serious here.

The matter of sectional chlorosis was brought up by Mr. Alexander. Mr. North stated that they had this trouble in Australia and that it was especially common on the variety D 1135. In Australia it was believed to be associated with cold weather when standing water existed around the central cylinder of the stalk.

Dr. Brandes said they had this trouble in Louisiana and had at first considered the cause of much the same nature as described by Mr. North. Later, however, they obtained the disease in their greenhouses in Washington, eliminating the possibility of its being associated with cold weather. He believed the trouble to be due to either extreme of temperature when there was an accumulation of water in the leaf spindle.

In Hawaii the disease has been reported from Olaa, Honokaa, Ewa and Waianae, according to Mr. Lee, but usually has disappeared without any serious harm, within one or two months. The theory of frost injury, as advanced in Australia, apparently could not be applied to such conditions as exist at Ewa and Waianae. The varieties affected have been D 1135 and H 109.

Sugar Cane Quarantine (By H. L. Lyon)

On Wednesday morning, July 30, the delegates of the cane sugar section assembled at the Territorial Plant Quarantine Station and inspected the laboratory and equipment employed in carrying out the local quarantine regulations. They then visited the cane quarantine house of the Hawaiian Sugar Planters' Association. This house was not entered but was carefully inspected from the outside. The delegates next assembled in the administration building of the Sugar Planters' Experiment Station and engaged in a general discussion of the subject of sugar cane quarantine. The points of especial interest to Hawaii brought out in the discussion may be summarized as follows:

As the sugar cane plant was not indigenous in Hawaii, all diseases and insect pests specific to this plant now present in these islands must have been introduced from outside sources. It follows, therefore, that had adequate quarantine measures been in force from the very first, cane in Hawaii might still be nearly or quite free from its specific enemies.

Laws regulating or prohibiting the importations of propagating material of sugar cane can be considered detrimental only to the country making these laws. It is no hardship to any cane-growing country to have cuttings of its cane varieties refused entrance into any other cane-growing country.

Travel and commercial intercourse between countries afford many avenues through which cane insects and diseases may be transferred from one country to another. It is quite impossible to close some of these avenues and impracticable to close others by quarantine regulations. It is obvious, therefore, that no practical quarantine can afford absolute protection against the entrance of the insect pests and diseases of the sugar cane into new territory.

While the danger of general dissemination of cane insects and diseases will grow with the increase of travel and commerce between the countries of the Pacific, still the danger will, at the same time, be lessened through the growing knowledge of these pests and the application of successful measures of control in the various cane-growing countries where they occur.

It is quite possible to surround the importation of cane cuttings into a country with such precautions that the liability of introducing insect pests and diseases with the cane will be less than that attending ordinary travel and commercial intercourse. This condition has quite evidently been attained through the quarantine measures now in force in Hawaii.

While there is no case on record where a cane disease or insect pest has been transferred from one country to another on dry cane tassels, still it is quite possible that certain cane diseases may be carried on such material and importations of seed should always be handled with great care.

Sugar Cane Entomology (By O. H. Swezey)

The session of the sugar industry section of the Pan-Pacific Food Conservation Conference occurring on the afternoon of August 6, was devoted to discussions on sugar cane entomology. Mr. Swezey was the leader and at the be-

ginning of the program gave a somewhat lengthy account of the major sugar cane insect pests in Hawaii, the history of their occurrence, whence they came, their habits and the damage caused. The method of controlling these pests by the introduction of natural enemies was outlined, with an account of the different parasites introduced for the respective pests.

Pest	Introduced Parasites	From
Cane Borer, *Rhabdocnemis obscura*	*Ceromasia sphenophori*	New Guinea
Leafhopper, *Perkinsiella saccharicida*	*Paranagrus optabilis*	Australia
	Anagrus frequens	Australia
	Cyrtorhinus mundulus	Australia
	Ootetrastichus beatus	Fiji
	Haplogonatopus vitiensis	Fiji
	Pseudogonatopus hospes	China
	Ootetrastichus formosanus	Formosa
Root grub, *Anomala orientalis*	*Scolia manilae*	Philippines
Aphis sacchari	Several ladybeetles	Australia
	Micromus vinaceus	Australia
Leafroller, *Omiodes accepta*	*Chalcis obscurata*	Japan
	Microbracon omiodivorum	Japan
	Trichogramma minutum	U. S. A.

Mr. H. Freeman, of the Colonial Sugar Refining Company, gave an account of experiments in the control of the cane grubs in Queensland. The two species most injurious to cane there are *Lepidoderma albohirtum* and *Lepidiota frenchi,* and loss by their grubs often is as much as 60 per cent. The adult beetles have their flights at certain definite seasons, and "it was found that there were two main reasons why any particular field of cane was selected by the beetles for the deposition of eggs. These were: (1) the height of the cane, and (2) the proximity to feeding trees. As an example, it was found that fields of cane which were six to nine feet high at the time of the beetle flight were infested to extent of an average of 6 to 14 grubs per stool; whilst cane which was only 6 to 18 inches high averaged considerably less than one grub per stool. From this a control measure was evolved in which a fast growing variety was planted during the beetle flight and pushed ahead by the use of a suitable manuring program." The beetles went to other fields of higher cane for egg laying and this field grew a crop without infestations. By harvesting fields just before the beetle flight, the new ratoons would also similarly escape becoming infested.

This control measure could not be utilized on all fields on account of various labor considerations. By experiment it was determinted that a saturated solution of paradichlorobenzol in carbon bisulphide was 2 or 3 times as efficient as either of the constituents used alone. A mortality of 80 per cent to 90 per cent of the grubs was obtained by using this fumigant. The increased yield obtained due to the fumigation made it a profitable investment. This fumigation had no detrimental effect on the growth of the cane providing it was over 4 or 5 months old. Younger cane was seriously affected.

Mr. Barnett, also of the Colonial Sugar Refining Company, told of the cane borer Tachinid being established in northern Queensland, and that it is being distributed to other parts of the State. He also told of its being established and

doing well on the Rewa River, Fiji, but that it has not succeeded on the opposite side of the island, though continued efforts have been made to establish it there. The borer has destroyed as much as one-third of the season's sugar crop at one center. Referring to a recent report by Mr. Veitch, Entomologist of the Colonial Sugar Refining Company, Mr. Barnett discussed some minor pests of sugar cane in Fiji. Among them was the armyworm, and he spoke very highly of the value of the mynah bird in preventing armyworms and grasshoppers from becoming extremely destructive pests.

Mr. Ishida, Chief of Shinka Sugar Experiment Station, Formosa, read two papers, one on "The Application of *Metarrhizium anisopliae* for the Control of *Allisonotum impressicole* and Allied Beetles," in which it was shown that the use of the fungus reduced the number of beetles and grubs about 50 per cent; the other paper was on "The Application of *Phanurus beneficiens* Against Stalkborer and its Result." This is an egg-parasite introduced from Java in 1916, and it has succeeded so well, along with other egg-parasites already present, that at present the damage to the cane from stalkborers is not serious.

Professor Osborn, of Ohio State University, who has made much study of leafhoppers and their economic importance, cited cases of the migration of some species from tropical America north into the United States, and warned of the likelihood of such species becoming pests in the new places they invaded. He said that in a recent letter from an entomoligist in Africa, the corn leafhopper was said to have been found infesting cane. It has never yet been known to do this in Hawaii.

Dr. Williams, who had recenly returned from a two years' parasite trip in various South American countries, read a paper on "Insects Affecting Sugar Cane in South American Countries." In this paper the worst pests in various places respectively were: Barbados—root grubs, *Phytalus smithi* and *Diaprepes abbreviatus;* Trinidad—the froghopper, *Tomaspis varia;* British Guiana—moth borers, *Diatraea* spp.; Brazil—froghoppers and *Ligyrus* beetle; Ecuador—moth borers, *Diatraea* spp. and weevil borer, *Metamasius.* Many other minor pests were mentioned. The most of these cane pests are insects native to the regions, and previously feeding on other plants, but have taken to feeding on cane after the introduction of the latter by man. Some of them are partially controlled by natural enemies.

Mr. Kay stated that the principal cane pest in Porto Rico is the white grub.

Professor Cockerell, of the University of Colorado, stated that he had noticed by a report from the entomologist in Egypt, that the mealybug, *Pseudococcus sacchari,* was the worst cane pest they had there, and that it really threatened the prosperity of the sugar industry in Egypt. While in Madeira Islands a few years ago, Professor Cockerell had found this same mealybug, but exceedingly scarce, apparently being destroyed by the larvae of a small *Leucopis* fly. This should be worthy of investigating further, for it might be that the fly could be introduced to Egypt or other countries desiring enemies to this particular mealybug.

Mr. Pendleton reported termites to be the worst cane pests in Gwalior State, India. They often eat the seed before it begins to germinate. If they do not attack the cane until it is pretty well grown, they work up through the stool in the

inside of the cane, filling the stalk with mud as they go. Many insecticides have been tried, but all ineffectual. The second pest is the cane borer.

In the absence of Mr. Van Zwaluwenburg, of Los Mochis, Mexico, Mr. Swezey presented for him a paper on the "Insect Enemies of Sugar Cane in Mexico." Two Pyralid moth borers, *Chilo loftini* and *Diatraea lineolata,* were mentioned as the only serious enemies of sugar cane in the state of Sinaloa, the former being by far the more important. No field methods for controlling it have been found. It infests many grasses, also corn, sorghum, and rice. A few native parasites attack this pest, chief among which is a *Chelonus* that has been known to parasitize as high as 23 per cent. Although second in importance, *Diatraea lineolata* has been known to infest from 35 per cent to 60 per cent of the cane stalks. It is primarily a pest of the plant cane. This is better controlled by natural enemies than *Chilo.*

The eggs are often parasitized to the extent of 70 per cent by *Trichogramma minutum.* In one state a Braconid, *Apanteles diatraeae,* has parasitized as high as 50 per cent. Attempts have been made with introduction of four parasitic flies, two from Cuba, one from Vera Cruz, and one from New Orleans, but so far none of them have been recovered. Minor cane pests in Mexico are: armyworms, leafhoppers, froghoppers, Membracids, the cane lacewing, mealybugs, and a weevil borer, *Sphenophorus incurrens.*

Rodent Control (By C. E. Pemberton)

In the session of the sugar section of the Food Conservation Conference devoted to rodent control, it was of particular interest to learn:

1. That rats actually do cause serious losses to cane in other countries. For instance, Mr. M. S. Barnett, of the Colonial Sugar Refining Company of Australia, stated that in 1921 a loss of 4 per cent of the total crop at two of their Australian mills, was attributed to rat activities.

2. That systematic poisoning has been proven effective in rat control in Australia and Cuba, though it has not been so extensively conducted as in Hawaii.

3. That phosphorus is the favored poison in Australia, and strychnine in Cuba. Barium carbonate has apparently not been tried in other countries to any great extent.

4. That rats are not so chronically serious in other cane countries as in parts of Hawaii, and that this condition is probably owing to the presence of natural rodent enemies such as snakes, owls, and hawks, in those countries. Mr. H. Freeman referred to the carpet snake of Australia, stating that it was common in some cane fields and that he had in many instances found the remains of rats inside them. Mr. Barnett also stated that these snakes had been seen to catch rats in buildings in Australia. They are not poisonous. Mr. Wood, of Cuba, also referred to two non-poisonous Cuban snakes which are said to be good ratters. Dr. F. X. Williams noted a non-poisonous British Guiana snake known as the "Yellow Tail," which is considered a very good rat catcher.

Interesting mention was also made by Mr. Barnett of useful hawks in Australia; by Dr. Williams of a beneficial bird of prey, the Caracara of Ecuador; by Mr. Wood of an iguana, owls, and hawks, of Cuba; and by Mr. Freeman of a so-called iguana of Australia, and of useful hawks. All admitted that these various natural enemies of rats had a weakness for chickens.

5. That rats in Australian cane fields damage cane only in sections of fields adjacent to permanent water supply. This point, brought out by Mr. D. S. North, is of particular interest, because rat damage in Hawaiian cane fields shows no relation, so far as observed, to the availability of water.

Sugar Cane Breeding (By Twigg Smith)

The good results that have attended careful crossing of sugar cane varieties is creating more interest in this type of seedling propagation.

The object of all cane breeding work is to obtain a cane which will have a combination of the qualities that are necessary for the production of a high sugar yield. Many canes otherwise good are weak in stooling or subject to attacks by disease.

Again, a hardy, heavy tillering cane may not produce enough sugar to make it a commercial cane.

The combination of good qualities of different varieties, then, would constitute the super-cane.

An endless amount of effort spent year after year in producing hybrids, by any method, from any two varieties, has little chance of success in producing the super-cane unless (a) proper study is given to the inherent characteristics of the parents; (b) their behavior under climatic conditions where the seedlings are to be grown commercially; (c) whether their characteristics, desirable and undesirable, are capable of being transmitted to their hybrid offspring.

Already certain characters and qualities of sugar cane have proved to be transmissible.

The discussion for the most part was by men actually engaged in sugar cane breeding work. The outline presented by Dr. Brandes for thorough discussion of the subject follows:

1. Selection of parents.
2. Varieties naturally inclined to bloom.
3. Environmental conditions affecting blooming or maturity.
   a. Latitude, daylight.
   b. Altitude.
   c. Temperature.
   d. Drought or excessive rain.
4. Technique of crossing.
   a. Methods for determining viability of pollen:
      (1) Iodine test.
      (2) Germination on stigmas of other plants.
      (3) Germination on sugar solutions.
   b. Methods for collecting and preserving pollen.
   c. Periodic viabiity of pollen during blooming season.

d. Methods of applying pollen:
   (1) Dusting.
   (2) Suspending male panicles.
e. Diurnal variation in opening of florets.
   (1) Receptive period of stigmas.
f. Protection of fertilized flowers against contaminating pollen:
   (1) Cloth bags.
   (2) Waxed paper bags.
   (3) Isolation by distance.
g. Harvesting of seed:
   (1) Bagging previous to maturity.
h. Viability of perfect seed:
   (1) Time to plant.
   (2) Time required for germination.
i. Methods of planting:
   (1) Rate of planting and position in relation to medium.
   (2) Soil.
   (3) Water requirement.
   (4) Provisions for preventing seed mixtures or pot contaminations by wind.
j. Transplanting—elimination of undesirable seedlings.
k. Packing seed for shipment.
l. Uniform methods for designating parents and time of producing seedlings by standard record.

Dr. E. W. Brandes said: "If we hope for progress in the way of actually improved varieties we have to go into breeding much deeper than just taking any two canes and crossing them: we must make a study of the possibilities that lie in the various varieties and fit them in with the various problems that have to be met. Conditions may arise, such as the introduction of a new disease, which may make new varieties necessary."

Selection of Parents: Under this heading it was stated that each country had its disease troubles, and the natural desire is to get a cane that would be immune to disease and at the same time be a good sugar producer.

In Hawaii, efforts are being made to combine the desirable characters of H 109, Badila, and D 1135 on one side, with the hardier, disease-resistant and heavy stooling character of Uba,* in an effort to avoid eye-spot, root-rot, yellow stripe, mosaic, etc. Also the so-called Tip canes are being crossed with D 1135 for higher lands. The Tip canes are vigorous growers at high elevations, but susceptible to mosaic and to red stripe disease. On the other hand, D 1135 is very resistant to eye-spot, mosaic, and red stripe disease, and ratoons well, but does not do as well as the Tip varieties above 1500 feet elevation.

We are also trying many field-gathered crosses of H 109 and D 1135.

Mr. Clarke said that in Fiji, Badila is favored as a mother cane, and they would like a combination with such a cane as Yellow Caledonia or H 109.

Mr. Ishida said that in Formosa, their main enemy is Sereh, and that effort was being made to get seedlings resistant to it. They are trying several varieties, including Yellow Tip, Rose Bamboo, Badila, and Kassoer.

In Cuba, Dr. Calvino stated that Uba, with D 74 as a male parent, had been useful in producing disease-resistant seedlings. They also imported seedlings from

* The local cane of the Chinese type labelled "Uba," and not yet positively identified.

Barbados and British Guiana. The parentage was not stated. Dr. Calvino said they took a great interest in raising seedlings because the seedlings may show characters which were not apparent in the parent canes.

Mr. Pendleton said that the problem in northern India is to produce a thick cane that will grow well under adverse conditions, notably, low humidity, little irrigation, and serious infestation of termites. In reply to a question, he stated that experiments had demonstrated that the thin-stick North Indian varieties were outyielded by their hybrids having larger sticks.

The question of transmission of susceptibility to disease by parents to seedlings was discussed at considerable length.

Mr. Agee cited the case of H 109, an Hawaiian seedling which is planted to 70,000 acres and gives very high yields and is immune to what is termed Lahaina disease or root-rot. This cane is a seedling of Lahaina, which is extremely susceptible to the disease. The seedling H 109 was produced without knowledge of its male parent, but it is thought to be Rose Bamboo or the family to which Rose Bamboo belongs. Rose Bamboo is also susceptible to Lahaina disease. Both Rose Bamboo and Lahaina failed at Ewa plantation, where the world's record yields have been made by their progeny, H 109. Another instance is a cane we call the Uba Hybrid No. 1. We were very desirous of obtaining a cane immune to yellow stripe disease. Following the lead of Dr. Calvino of Cuba, we crossed Uba with D 1135, both parents being commercially resistant to yellow stripe. The hybrid No. 1, however, has well developed cases of yellow stripe or mosaic.

"I think," said Mr. Agee, "that these two cases prove that we cannot be too closely bound by theory in cane breeding."

Dr. Brandes expressed the opinion that the cases mentioned by Mr. Agee were exceptions which prove the rule that like produces like, and that a cane immune to disease has a greater chance to produce immune offsprings. He also pointed out that he had seen yellow stripe on D 1135 in the Philippines.

Mr. Agee stated that at Honokaa a fair percentage of Uba seedlings had yellow stripe disease. It was important, he thought, to note and study these exceptions to what might be expected. It is not the characteristics of the parent canes that we are primarily concerned with, but the characteristics that they are capable of transmitting to their progeny.

Dr. Brandes stated that in trying to get a variety resistant to sereh, in Java, they had crossed their Black Cheribon with Chunnee from northern India. They succeeded in getting seedlings, immune to sereh, but susceptible to other diseases, notably, yellow stripe or mosaic. At the present time they are concentrating on crosses of native canes and the primitive types of sugar cane. The seedlings obtained are then crossed with the heavy-yielding canes, and they have now several promising seedlings, such as P. O. J. 2714, 2725, etc., which are resistant to most diseases. Many of them are commercially immune to mosaic and also the disease referred to as root disease.

Mr. Barnett stated that in the case of a New Guinea variety called Mahona, imported to New South Wales, it was noticed that it had a tendency to die off in the tropics, due, it was discovered later, to a disease called leaf-scald. Many seed-

lings had been raised from Mahona, and the majority inherited susceptibility to the disease.

Under the topic of "Blooming or Tasseling," it was brought out that all varieties bloom in Hawaii, and it seems well established that the blooming is best in the medium altitudes. Instances were cited where, on Hawaii, cane did not bloom at 3,000 feet nor at 50 feet, but did bloom between these levels.

It was stated that all varieties bloom at times in Fiji and Formosa.

It seemed generally accepted that anything that checks the growth of the cane seems to cause the plant to arrow, tasseling being considered a normal process of sugar cane.

Under the heading of the "Technique of Crossing," the first discussion was on the methods of determining the viability of pollen. The method favored at present at this Station is to determine by miscroscopic examination if the pollen is spherical and contains granules, in which case it is considered normal. The presence of starch as indicated by the well-known iodine reaction test is in exact relation to the normal state of pollen grains, which are spherical, juicy, and full of granules of starch. We did not succeed in germinating pollen on any of the artificial media tried last year.

Dr. Calvino told of success in germinating pollen on stigmas of other plants, but not in any solution. Mr. Clarke reported a complete lack of success in germinating pollen in any way in Fiji.

Dr. Brandes said that in Florida they had successfully used the moon vine, a species of Iponea.

In Hawaii, the method of collecting pollen has been to suspend the tassels over a table, which is covered with black paper, and as soon as the pollen had dropped, to sweep it into a container and immediately dust it on the stigmas. No satisfactory method of preserving pollen has been found; rather, it seems to be very fugitive, quickly drying under changes of temperature and humidity. We have never been able to keep it looking spherical above 10 minutes if exposed to much light.

Under the topic of "Periodic Viability of Pollen," Dr. Brandes pointed out that observation had been made in many places that pollen may be viable at the beginning of the tasseling period and worthless toward the end, and that it is extremely important that we should know just the best time, with each variety we desire to use, to take pollen for cross pollination. The period of non-viability of pollen would be the best time to use that particular variety as a female parent.

No definite data appeared to have been kept as to the best method of applying pollen to the stigmas of the female variety.

Good results have been secured in Hawaii by two methods, tying the male and female tassels together, and by collecting the pollen on paper and brushing it on the stigmas.

Speaking on the variation in the receptive condition of stigmas, Dr. Brandes stated that under local conditions in Florida it had been found that stigmas of sugar cane were receptive from 3:40 A. M. till daylight. An effort will be made in Hawaii this year to determine that for our varieties.

It was generally agreed by those who had used bags to protect the tassels that it is not to be recommended. The tassels are weakened, and germination of the seed is weakened. In general, where a large number of seedlings are wanted, it seems to be considered enough to gather the pollinated tassel in the field from a place where it is fairly reasonable to suppose the desired cross has been effected. Until some method of carrying on artificial cross pollination on a large scale is found, this method of getting crosses will probably continue in most countries.

Dr. Brandes stated that in Florida they now make a practice of waiting a week or so after the last male tassel has been placed in contact with the female, and then put a cloth bag over the pollinated tassel to prevent wasting of prospective seedlings. In Hawaii, the practice is to wait till the fuzz flies from the top of the tassel on being lightly tapped. The tassel is then considered ripe enough to gather. Sometimes the panicle is cut in sections for planting so as to avoid the loss of mature parts.

The time that seed can be held before being planted seemed to vary in each country. In general it seemed that the sooner it was planted the better, although Dr. Brandes told of seed sent from India to Washington, D. C., which germinated very well.

On the question of how long the fuzz should be kept in the hope of germination, it was brought out that cane tassels had continued to give germination for as long as thirty days.

Mr. Kutsunai outlined the Hawaiian method of planting seed, which is to distribute the fuzz on top of sterilized garden soil and sand. The fuzz is kept very moist.

The method of Mr. W. P. Naquin, at Honokaa Sugar Company, of using well-seasoned filter press cake alone, on which the fuzz was spread, has given remarkable results, and probably is as good a medium for getting germination as any used so far.

Dr. Brandes said the U. S. Experiment Station in Florida uses clean fresh-water sand, which is practically sterile, and from which they have had good results.

Mr. Clarke stated that in Fiji they use a glass house, and the temperature ranges from 120° in the day to 60° at night, but even at that they get very excellent germination.

Mr. Agee stated that large cold frames with glass protection were used very successfully in Kohala and Hamakua. These gave a very high temperature.

Steam heat will be tried as a subsoil heat this year here in Hawaii, and Dr. Brandes stated it was his intention to try the same in Florida.

Also this year in Hawaii some seedlings will be germinated in a glass house so made that it will be possible to roll the flats out in the fresh air on still, dry days. The time of germination in Hawaii is January and February, which are normally our wettest months.

In discussing the elimination of undesirable seedlings it was brought out that in Fiji, Formosa and in Florida it is customary to discard by inspection, after one year's growth, from 95 to 98 per cent of the canes. In Hawaii, the initial

discard is not so high, usually being from 60 to 80 per cent, sometimes 90 per cent.

Dr. Lyon questioned the advisability of severe elimination of canes the first year, and thought that there was an opportunity for valuable scientific investigation in this connection. Both he and Mr. North cautioned against selecting with a preconceived type in mind, feeling that the superior cane sought in this work may appear in a form different from the commercial canes of today. Mr. North cited Badila as an example of a valuable cane which would be eliminated if grown in competition with other varieties closely spaced about it.

Mr. Moir strongly favored ratooning the original seedling plants and cited the Wailuku seedlings in support of his contention. Initial selections based on plant cane were found inferior by him to canes originally overlooked and afterward selected by him from the old ratoons of the original plants. Mr. Kutsunai pointed out that at the Manoa substation a large number of seedlings were being ratooned this year from the original plants, and he stated that with one exception he had been able to select as plant cane those seedlings which afterward showed to good advantage as first ratoons.

On the question of the spacing of the original plants, it was found that spacing of four or five feet was utilized in Fiji and Formosa and even wider spacing in Florida. In Hawaii, a spacing of plants three feet apart in five-foot rows has been gradually reduced to two feet. On the strength of recent trials of five-foot spacing, however, there is an inclination to adopt this in the future.

Dr. Brandes described a score card system of judging canes with the view of reducing to a minimum the personal equation in selection. Cane breeders in Hawaii, Fiji and Formosa agreed to give this score card system a trial under their conditions. Dr. Brandes laid great strength on the strong root system. This, he said, must be considered as a prerequisite of any seedling that is to be retained.

It was also pointed out that when one adopts wider spacing or is slower in eliminating apparent undesirables in a large block of seedlings, he thereby curtails the space that might be devoted to newly propagated ones. To thus reduce the number of germinations is in effect an elimination in itself of those not germinated, and this must be borne in mind in any further study to perfect our methods.

Bud Selection (By Y. Kutsunai)

Mr. Harry Flockton Clarke, of Fiji, presided at this meeting.

That there are mutations of sugar cane is an established fact. The sporting of Striped Mexican into Rose Bamboo, of Red or common D 1135 into yellow-striped D 1135 and bronze-striped D 1135, and finally into the so-called white D 1135; of H 109 into striped H 109, and of Yellow Caledonia into striped Caledonia of various colors, is very well known to Hawaii and needs no evidence to prove its occurrence. The color mutations are naturally the first to be noticed because the mutating qualities are not only clearly visible but also are *independent* of the environmental factors.

The heavy-yielding mutations, which are also thought to exist, as indicated by several tests, are not clearly seen on account of the overpowering environmental influences. How often these heavy-yielding mutations occur and recur in the cane fields is not definitely known at the present state of knowledge of the subject. The frequency with which the striped sport of H 109 occurs may possibly throw some light on the point in question. Eight stools of striped H 109 were found in about 25,000 stools of H 109, or a ratio of 1 in 3,000, roughly. A high-yielding mutation, if rare, as it is thought by some to be, and masked by the environmental factors is not easy to spot. The history and the methods of selecting or isolating high-yielding mutations so far evolved or suggested, and the attending difficulties were well discussed and many points of interest were set forth. A review of these points and ideas follows.

The work of selecting mutations in sugar cane by Mr. A. D. Shamel was begun in 1920. His first activity was that of training a staff of selectionists to develop keen powers of observation. The course consisted of taking a very detailed census of a cane row, noting the position of the stalks, the number of stools per seed piece, the number of stalks arising from a single eye, the length, circumference, and weight of the stalks, the number of joints in the stalks, juice analyses, color types, and uniformity.

When the staff became sufficiently acquainted with the cane plant, the actual selection of superior stools was initiated. The cane selected was always plant cane.

The fundamental idea of the bud selection is to segregate a given variety of sugar cane into its component strains and at the same time to isolate any mutation that may exist or be thrown out in the course of work. From such strains and mutations, the high-yielding lines are to be isolated. These isolated lines may revert back to the original variety or may throw off other new lines.

Two lines of procedure have been developed. In one, a plot of cane is stripped and every stool is examined. Superior stools of cane are chosen for further trial. Due allowance is made for extraneous influences, such as a near-by watercourse or a ditch, proximity to the edge of the field, etc., at the time of judging the stools. The other method consists of covering as wide an area as possible, without the preliminary stripping and picking out of very striking stools, and planting them under uniform conditions for further selection.

In applying the theory of bud selection to practice, two tendencies have been developed. In the one case, the selectionists have laid stress on the so-called types, or conformation of sugar cane. The erect, semi-erect, and the recumbent types of H 109 have been studied carefully in relation to the yielding power of the types. The selectionists of this school hold that a variety of sugar cane, H 109, for instance, is made up of many strains that are well nigh stable. The segregation or resolving of a variety into its component strains is followed by the comparative studies of the segregated strains in order to find the most desirable one. The other school believes that the high-yielding quality of a variety of sugar cane may be correlated with two kinds of characters, visible and invisible. Selection

based on this idea is necessarily very wide in its latitude. Not only all the promising types are accepted, but also all the superior stools are selected for further trial.

The selection work seems to be a rather involved proposition on account of the overwhelming environmental influences which obscure the differences in the yielding qualities of various strains of a sugar cane variety. Consequently the work is now taking a decided turn and the problem of the immediate future is the development of methods by which the disturbing environmental factors may be unified or held in check. The most important cause of the difficulty is the uneven distribution of the elements on which the cane makes growth, such as light, fertility, and water. The "necessities of growth," if allotted to each stool in equal amounts, the inherent characters of the stools become apparent. The method that promises to, in part, fulfill the desired aim, is spaced planting. The selected stools are planted far enough apart so that each stool can have more room for natural development.

Another turn that is taken in the procedure of bud selection work is the study of ratoons. Heretofore most of the work was done in plant crops about a year old. It is reported that a ratoon crop, especially an old ratoon crop, has been noted to be very promising material for selection.

On the whole, the problems confronting selectionists are very much more involved than anticipated. Unless one is fully prepared to meet discouraging results, and unless one has firm conviction and faith in the work, and has originality and resourcefulness to overcome the stumbling blocks that beset the work of bud selection, he is likely to fall short of his goal.

Sugar Cane Cultivation (By J. A. Verret)

The meeting was presided over by Mr. Hunter Freeman, of Australia. Those taking part in the discussion were Messrs. M. S. Barnett and H. Freeman, of Australia; Mr. H. F. Clarke, of Fiji; Messrs. Kintaro Oshima and Migaku Ishida, of Formosa; Mr. R. H. Van Zwaluwenberg, Mexico; Dr. Mario Calvino, Cuba; Mr. R. L. Pendleton, India; and Messrs. H. P. Agee, Guy R. Stewart, W. P. Alexander and J. A. Verret of Hawaii.

We shall outline briefly important points brought out in discussions in the order in which they were presented.

As this is intended for Hawaii readers, for the sake of brevity, parts of the discussion relating to Hawaii will be omitted.

Rotation and Green Manuring: Dr. M. Calvino, speaking for Cuba, pointed out that no rotation is practiced in Cuba, and no irrigation. In a few cases some green manuring is being done experimentally. The velvet bean is used for this purpose with good results. Jack beans have also been tried. The velvet beans are planted broadcast, and plowed in before they mature seed.

Mr. Pendleton, speaking for India, said that agricultural conditions were rather poor in that country. In preparing the land for cane, a wooden, steel-tipped plow is used. This goes down, at the most, about four inches. But the Indian farmers

make up for this to some extent by plowing the land as much as twenty times before planting.

A system of rotation for sugar cane has been recently introduced with promising results. It is one of three years, and starts with sugar cane, planted in the winter season. This grows for one year, and no ratoons are taken. After harvest the land lies fallow until the rainy season, about June or July, when san hemp, *Crotalaria juncea*, is planted. This is plowed under in September, after which the land is planted to wheat. This crop gets one or two irrigations, and is harvested in March or April. The land remains idle until June, when another legume, guar, *Cyamopsis psorolioides,* is planted. This is cut about September, and used for fodder, sometimes being made into silage. Cane follows this, being planted about December, starting a new cycle. Some irrigation is practiced. This applies especially to northern India. The yields are rather small in India, 18 tons of cane per acre being about maximum.

In Fiji there is no irrigation. As a general rule three crops are raised, one plant and two ratoons. This is followed by a green manure crop, black Mauritius beans usually. A fair crop of beans gives about 10 tons of green matter per acre. This is plowed under.

In regard to trash conservation, Mr. Clarke, speaking for Fiji, made the following statement: "Formerly we saved the trash. This was made into piles between the cane rows and after the harvesting of the last crop this accumulation of trash was plowed under. We found a certain benefit from this, but we also found certain disadvantages. The ratoons were hampered in their growth by the banks of trash, which did not rot readily. At that time we were only growing plant and first ratoon crops. Now we do not save any trash except that from the last ratoon crop."

Mr. Van Zwaluwenberg, referring to the western part of Mexico, said that irrigation was the common practice. The fields are ratooned from two to four times. The old lands generally raise but two ratoons. The cane is followed by alfalfa. This grows for two years, cutting the first year and grazing the second. In some cases a short cover crop is put in. This is planted in May or June, and grazed. Cane follows, being planted in the fall or spring. The cane grows for 18 months to 2 years.

In Formosa, some areas are irrigated and some are not. The cane crops consist of one plant and one ratoon. This is followed by a crop of sweet potatoes, and this in turn by peanuts. Cane ratoons very poorly in Formosa.

In Louisiana, a three- or four-year rotation is followed. This consists of one plant crop of cane, one ratoon, and then corn and cowpeas, the cowpeas being plowed under. The four-year rotation is the same except that there are two years of cowpeas and corn instead of one. Cane in Louisiana is about a 9 months' crop. Frosts kill the cane down in winter. These frosts are likely to come along any time from November to March. The average yearly yields of cane vary from about 11 to 18 tons per acre.

In Queensland and New South Wales, the practices are given as follows by Mr. Freeman: "The plant crop is usually about 15 months old and the ratoon crop

occupies the land for 12 months. Generally speaking, we cut two ratoon crops, but on some occasions it runs to third ratoons. This depends upon the prospect of a profitable yield. The trash is certainly not saved. The period of fallow varies, but usually it is only a matter of time sufficient to prepare the land for a subsequent crop. Undoubtedly there are farms that practice green manuring, and they find the benefits of it. It gives handsome yields in Queensland. I think there are various reasons for that, but mainly it serves as a weed control, and supplies humus. The green manure crops are Mauritius beans and cowpeas. Of these the Mauritius bean is undoubtedly the better, for the reason that it holds the ground longer. But it must be plowed under before it produces seed. The ground is well covered for four or five months. We get maximum yields of 10 to 15 tons of green matter per acre. In Queensland we might say that the average cane crop is about 20 tons per acre. We get maximum yields of 60 to 70 tons per acre from year-old crops, but they are exceptional, and these only occur on new lands, recently brought under cultivation. In New South Wales, the climate is colder and the rainfall more even. There we have two-year-old crops of both plant and ratoon cane with yields of 50-100 tons per acre. Very little green manuring is regularly practised, but there is a certain amount of rotation with corn. There is very little done in the way of green manuring, either in Queensland or in New South Wales, but we feel the want of it very badly. There is one point in connection with green manuring that may interest you. For instance, with Mauritius beans, sown broadcast, we use a bushel of seed to the acre, whereas with a drilling machine half that quantity is sufficient, and one man can cover four to five acres per day. It is quite evident that there are many different opinions on the question of rotation practice. Hawaii stands in marked contrast to the other countries in getting increasingly better results without either resting the land or by green manuring. After thirty years of cane growing here, they still get increasing yields from the same land, but in Queensland the opposite is the case. The longer we grow the cane there, the lower the yields, unless we practice green manuring."

Preparing a Field for Planting: New lands in Cuba are not plowed, as these are generally forest lands. Holes are made among the stumps with picks or other sharp instruments, and the cane planted in them. On the lands which are plowed, some of the smaller tractors are used, plowing to less than 12 inches. Oxen are still very extensively used for plowing.

As stated above, the Indian uses a steel-tipped wooden plow for his plowing, with which he may scratch the field 20 times. The other work is largely by hand. The manure is placed in the furrow and well mixed with the soil about six weeks before planting.

The cane is irrigated and has frequent cultivations, gradually filling in the furrow so that by the beginning of the heavy rains in June or July the cane is well hilled.

In Fiji, in plowing in trash, a 4-mule, single-furrow plow, with a 26-inch disk, is used. The furrowing is done with a double mould board to a depth of 7 or 8 inches.

Some steam plowing (Fowler) is done on one plantation. Some tractors are used, the largest being about 45 h. p.

In Formosa, native plows and some tractors are used. The native plows go in about 5 inches. Seven or eight sets of Fowler steam plows are also used. Tractors and steam plows are used on the large plantations only. The small farmers confine themselves to the native plows. Fordson and Case are types of tractors used.

Mr. Freeman gave an interesting resume of the work in Queensland and New South Wales. We quote him: "In regard to Queensland and New South Wales, the plows are of various types. Usually disc plows are used in all preparatory cultivation work. One of the great obstacles in returning humus to the soil in preparatory cultivation has been the difficulty in finding plows suitable for turning under trash or bean crops. Special study has shown that a single furrow disc plow gives best results. The secretary disc is very satisfactory in so far as it has an arched beam which allows of great clearance. But we have modified the first furrow wheel and land wheel by using parts from more up-to-date plows, whilst the rear furrow wheel has been substituted by a disc Coulter. The sharp edge of this Coulter bites into the bottom of the furrow at the junction of the land and the furrow. Thus, by means of thrust, we have achieved what most plow manufacturers try to attain by weight. In consequence of this device, the plow is held to its work. Another point in regard to the satisfactory plowing under of green crops is that the disc needs to be as upright as possible; it must be at least 28 inches in diameter, and the edge kept as sharp as a razor by means of a long bevel and the constant use of a file. The dish of the disc should also be quite pronounced, and the furrow cut by it a full 12 inches. It is just these details which mean successful plowing.

"We believe that the desirable depth of cultivation is about 12 inches, but do not always achieve that. We are using more and more tractors every day. Steam cultivation is not used. My opinion is that a track-laying tractor is the only type to use. Many of the smaller tractors which work with one wheel in the furrow are employed. These are not necessarily preferred, but it is more a case of the inability of small farmers to purchase the larger or more efficient implement. Tractors give us a greater independence of labor by reason of their speed, and this speed is also a factor of importance in fitting in our work with weather conditions. They help us in labor problems, but, I am sorry to say, do not always mean more efficient work."

Planting: In India, whole stalks are planted without cutting, no top seed being used. The fields are irrigated ahead of planting, and the seed buried in the mud by hand (or feet, perhaps is a truer expression).

In Fiji, planting material is obtained from special fields called "seed beds." These are about ten months old when cut, and the whole stalk is used. In planting, the seed is placed 2 feet center to center, with rows 5½ feet apart. The seed is covered with ½ to 1 inch of soil in the rainy season and with about 3 inches in dry weather. When planting is done in the spring top seed is used, as the "seed beds" are not then ready.

These "seed beds" are carefully observed, and if any diseases, such as Fiji disease or mosaic, appear, the field is discarded for seed purposes. On this account both Fiji disease and mosaic appear to be under control, there being but little of either.

Except for this careful inspection for disease, these "seed beds" are not treated differently from the other fields.

In Cuba, as mentioned previously, forest lands are planted with a pick, using short seed. Another method is by means of a sharp, hardwood stick. The laborer walks along, and, at proper intervals, drives the stick in the ground at an angle; the stick is pressed up and pulled out, after which a seed is placed in the hole and the ground pressed about it with the feet. The advantages claimed for this system are that the seed has the benefit of the moisture in the bottom of the hole, and aeration, sunshine and heat at the surface.

Another system being tried out on a commercial scale was described by Dr. Calvino. This is called the Abreu system.

In this system the land is prepared and two seeds are planted in squares eight feet each way and covered with an inch of earth. No holes are used. At harvest only mature stalks are taken, the others are allowed to grow. As we understand this, mature stalks mean all millable cane. The stalks left behind are the immature suckers. Wagons are driven in between the cane rows to haul the cut cane.

In Formosa, both top seed and body seed are used. The seed is planted at an angle of 60° to 70°, and spaced 14 inches in four foot rows.

Mr. Freeman has briefly outlined conditions in Queensland as follows: "In regard to Queensland, usually we take seed from plant crops if possible. Some fields are often planted as seed beds, but no special precautions are taken in regard to them. In many cases seed cane is purchased from a neighboring farmer, but usually it comes from his own farm. We prefer plant cane about 9-10 months old. The seed is cut at right angles to the stalk and the ends are not shattered. This is possible with a soft cane like Badila, but the hardness of H 109 might force us to cut it on a slant as is done in Hawaii. We are afraid of the slanting cut on account of the greater area exposed to drying out. We usually use the whole stalk, but experimental evidence has shown that the tops give increased yields and slightly sweeter juice. These experiments were very carefully conducted. We do not soak the seed cane in water before planting unless the conditions are very dry. It is then a distinct advantage. Hand planting is a thing of the past. Queensland was the inventor of machine planting. It is a question of labor shortage, and I do not doubt but that very shortly you will be using machine planting here. These machines are of simple construction, consisting essentially of a box on wheels with a funnel through which the seed is dropped into the furrow whilst two feet on the rear of the machine cover over the pieces. Usually they work in the furrow, which has been made by a double mould board plow. The main feature about them is that they do the work well and save labor. Two units of labor will do more than five times as much work with the machine as they can with hand planting."

In Louisiana, whole stalks are used for seed. The bulk of these come from the poorest ratoon fields, and up to very recently no attempt was made at selection. Planting takes place in autumn or spring. The autumn planting takes place in September or October, before harvesting begins. The spring planting starts in February and proceeds as fast as weather allows. The seed for spring planting has to be kept over winter and protected from frost. This is done by cutting two rows on one, placing the cane in the furrow and covering with earth several inches deep. This keeps fairly well through the winter. The autumn planting remains in the ground all winter and begins to germinate in February or March, depending on the coldness of the season.

It is now becoming customary to plant a cover crop of sour clover on autumn plant fields. This is turned under when cultivation starts in the spring.

In preparing for planting, the fields are laid out in rows 5 to 6 feet apart. A planting furrow is made in the center of this row, not as deep as the bottom of the furrows between the cane rows, in order to allow for drainage. Wagons with the seed cane are driven in the fields and drop the cane in the furrow, usually two running stalks. Boys follow behind with cane knives, place the cane properly in the row, and cut the stalks into shorter lengths so as to have proper contact with the soil. Disc cultivators follow behind and cover the seed several inches deep.

In the spring the cane is off-barred, and excess dirt removed to allow germination. The off-barring incidentally covers most of the sour clover.

Soils and Fertilizers (By G. R. Stewart)

The meeting of the sugar section which dealt with soils and fertilizers was fortunate in having a group of delegates present from many of the important cane sugar countries of the world. The following cane regions had one or more representatives: Australia, Cuba, Fiji, Formosa, India, the Philippines, and Hawaii. A great diversity of conditions and agricultural practice was revealed in these different regions. It may be illuminating to summarize some of the outstanding observations upon sugar cane soils, and their fertilization, in these widely separated districts.

Australia: The principal sugar cane regions are in New South Wales and in Queensland. Both these districts are part of the coastal plains which extend north and south along the shores of the Australian continent for over 1400 miles. The Queensland cane estates lie in the northern section of this coastal belt, and the New South Wales cane land in the southern.

The soils planted to sugar cane show quite a wide variation. They may be divided roughly into the soils of the alluvial flats and the forest soils. The alluvial flats are deep soils which have been deposited along the banks of the rivers. This land was originally covered by a dense growth of tropical scrub. The soils formed under these conditions are inherently very rich.

The forest soils are, in general, lighter in texture than those of the alluvial flats, though occasional areas of clay occur in this forest land. The greatest dif-

ference between these two soil types is in productivity. The forest soils are notably poorer in yield than the alluvial flats.

There are also limited areas of true volcanic soils which are very similar to some of the soils of the Hawaiian Islands. In general, the Australian volcanic soils are more porous and open in texture than those found in Hawaii. This volcanic land is extremely deep and is inherently rich soil. In all the Australian cane land, moisture is the greatest limiting factor. This open texture of the volcanic soils, therefore, favors the passage of rainfall far down below the roots of the cane plant, and makes the growth of a crop a very great problem in dry weather.

Very little chemical work has been done upon the Australian soils. Dr. Maxwell made a small beginning in chemical work years ago when he was first in Australia. This work did not continue for any great length of time, though for many years government reports have been issued giving the analyses of the soils from various districts. These analyses were not correlated with any field experiments or attempts to determine the productivity of this land. There are no special problems of soil fertility under investigation in either sugar cane region at the present time.

The fertilizer practice which appears to give the best response in Australia is the use of green leguminous cover crops. The trash is usually burned before cutting the cane, in Queensland, and it is becoming very apparent that this is leading to gradual exhaustion of the organic matter of the soil. The use of green manuring crops has not become universal, but there is strong evidence that it is the best treatment for the cane lands of Australia.

At the present time, it is a fairly general practice to apply about 400 to 600 pounds per acre of a phosphatic fertilizer containing about 5 per cent to 7 per cent of nitrogen and 14 per cent to 16 per cent of phosphoric acid. This fertilizer is put on in the drill at the time of planting. If the ratoons are fertilized, it is customary to apply ammonium sulfate, but most of the fertilizer is applied to the plant crop at the time of planting. This practice is believed to stimulate germination of the cane and force the young growth ahead, so that weeds are more easily controlled. The cane crop in Australia is grown for a period of about twelve months, and the average yield of cane is about 25 long tons, or 28 short tons per acre.

Cuba: In Cuba, practically all the sugar cane lands are formed on a limestone base. There are two general types of soils: the dark red soils, and the heavy, black clay loams. For many years it was believed that cane could only be grown upon the red soils. It has now been proven that the best yields are obtained from the black soils. The red soils are very deficient in humus. Green manuring crops such as velvet beans and cowpeas are now being tried to restore the fertility of the older cultivated red soils.

All the cane soils have an apparently inexhaustible supply of lime. It was formerly believed that all that was necessary to restore the fertility of the sugar cane lands was to allow them to go back into wild growth as forest land. This is a very slow process for building up organic matter in the soil. The use of green

cover crops promises to be a much more rapid and effective way to restore fertility.

No extended chemical studies have been carried out on the Cuban soils and no fertilizers are being used at the present time. Nearly all the sugar companies have more land available for cane than is now under cultivation. With this extra land to draw upon, if necessary, and a sugar market which does not warrant a great expansion in production, the tendency in Cuba is to produce cane by the smallest possible outlay. The usual system followed is to cut the cane without firing. The cane tops are used as feed for the bullocks which draw the cane wagons and plow the fields.

The cane trash is allowed to lie in the fields and forms a heavy mulch which effectually prevents weed growth. The plant crop and the first ratoons will ordinarily require considerable cultivation and hoeing. After these two crops have been harvested there is ordinarily sufficient trash to keep down the weeds. The maximum crops obtained are about twenty-five tons of cane per acre. The average crop would probably be from fifteen to twenty tons of cane. The cane fields are ordinarily ratooned for fifteen to twenty years. Fields are not ordinarily replanted till the production of cane has fallen to about eight tons of cane per acre. The crop is grown for about twelve months, all fields being ordinarily cut each year.

Fiji: The best cane lands in Fiji are the alluvial flats, which lie between the low hills bordering the valleys and the rivers flowing through the center of them. A less desirable type of cane land lies further back at the base of the hills, where the soils are partly transported and partly formed of residual material by the weathering of the rocky deposits on the hill slopes. The poorest soils are the upper portions of these slopes, where the land has been subject to excessive washing and erosion.

At the present time, no chemical investigations in soil fertility are under way in Fiji. Many carefully controlled plot experiments have been carried out, comparing local seedlings with standard canes, and contrasting various soil and fertilizer treatments.

As a result of this work, green manure crops have been established as the best fertilizer treatment for the cane lands. On the best lands greater tonnages of cane could be obtained by additional fertilizer applications. The Fiji cane grower has actually found that it is not profitable to raise this maximum crop because of damage which will occur to it before harvest. Badila cane is still the standard variety in Fiji. If a moderate crop of Badila is raised, say about forty tons per acre, the crop will stay erect and will not fall down or lodge before it is cut. With a very heavy crop of Badila, running from 60 to 70 tons per acre, a great deal of the cane will lodge and fall down when rainy or windy weather comes. This results in damage to the stools and breakage and deterioration of the cane. When harvested this heavy crop may have as much as 50 per cent of dead stalks in the field. This has resulted in the policy of raising the maximum profitable crop of about 40 tons per acre, as it actually gives a better return in millable cane and leaves the stools in good condition for ratooning.

For the plant crop, on the rich alluvial lands, it is therefore customary to apply no fertilizer. The medium and poorer lands give a good response to applications of coral sand at the rate of 5 to 10 tons per acre. It is also customary to use about 200 lbs. of sulfate of potash and 300 lbs. superphosphate per acre for the plant crop on these poorer soils.

The ratoons on both good and poor soils receive from 200 to 400 lbs. sulfate of ammonia per acre. The experience, over a number of years, has led the growers to expect an increase of 5 tons of cane per acre for each hundredweight of ammonium sulfate that is applied.

It was formerly customary to save all the trash in order to maintain the content of organic matter in the soil. This also returned an appreciable portion of the potash and phosphates which had been removed by the crop. On account of shortages of labor it has been necessary to abandon this practice on the plant and earlier ratoon crops. The trash is still saved on the last crop harvested before plowing.

As previously noted, the maximum profitable crop for Fiji conditions is about forty long tons per acre. This is commonly obtained from the best land on the plant crop. The plant crop on the poorer lands and the average ratoons will frequently be lower, probably yielding about twenty-five to thirty long tons per acre.

Formosa: The cane soils of Formosa are largely alluvial deposits derived from clay slates and to a smaller degree from sandstone. The resulting soils are in many cases of a heavy clay texture, though loams and clay loams are also found. The soils have nearly all been mapped according to the German system, which was adopted many years ago in Japan.

Considerable chemical work has been done on all the Formosa soils in order to establish any existing relationship between the classification and the composition of the soils.. It is believed this work has developed information of considerable value in planning experimental work upon the fertilization of the cane land.

Extended investigations have been carried out in Formosa upon the reclamation of alkali land. Fortunately, the salts impregnating these soils are largely composed of the sulfates of sodium and magnesium, with smaller amounts of the chlorides of calcium, sodium, and magnesium. It has therefore been possible to reclaim these lands by very simple measures. A combination of drainage and irrigation has now converted some of these former saline areas into some of the most fertile soils in Formosa.

In order to determine the fertilizer requirements of the cane soils, field experiments have been carried on in thirty-four districts where different types of soil are located. In this work the attempt has been made by a study of the yields obtained by all possible fertilizer combinations and the analyses of the plants grown, to try and find the amounts of the different plant foods which the soils are capable of supplying. The general result of this experimental work has been to find that the soils of Formosa are more in need of nitrogen than of phosphoric acid or

potash. Some limited areas respond to phosphates, but very little return has been obtained from the application of potash.

One of the first studies undertaken in work upon fertilization in Formosa was the determination of the coefficient of availability of each of the constituents used in the commercial fertilizers. A great deal of work was done along this line and coefficients are now available for each of the commercial materials, when used under Formosan conditions.

The nitrogenous fertilizers most commonly used are ammonium sulfate and soya bean cakes. Some Chile saltpetre has been used, but there is considerable prejudice against its use because of possible loss from the heavy rains.

Green manuring is now considered one of the most valuable practices in Formosa. It has been calculated that a good green manuring crop will supply about 31 pounds of organic nitrogen per acre. It is now a common practice to grow a green cover crop at least once in three years.

It was formerly customary to burn all the cane trash, but latterly the attempt has been made to have the farmers return the trash to the soil. Where this practice has been followed, remarkable improvement has been noted. This is probably due to the great change which is made in the physical condition of the soil by working in the partly decomposed cane leaves. The Formosan soils are generally extremely heavy in texture. The cane ordinarily produces a poor root system in such land. After considerable organic matter is incorporated in this heavy soil, it becomes notably more loose and friable, and the resulting root system is far more extensive.

India: Sugar cane is grown in India upon a considerable variety of soils. The best cane lands are deep alluvial deposits, such as those which occur along the banks of the Ganges River. These soils are sandy loams to silt loams. Around Pusa, cane is grown upon a group of fine silty loams, which frequently may contain as much as 40 per cent of calcium carbonate. Going farther west, there are older alluvial soils which frequently contain undesirable amounts of soluble salts. In central India, there are many areas of heavy clay adobe, upon which cane is being grown.

In general, the soils of India are low in nitrogen and low in organic matter. This is not surprising when one reflects that these soils have been under cultivation for many hundreds of years. There has never been any general use of green manuring crops. Small amounts of cow manure are applied where it is available. A little oil cake has been used in some districts. A few of the more progressive commercial plantations are now purchasing ammonium sulfate. The native cultivators of India work their land to a very shallow depth, stirring the soil for a few inches with a small wooden plow. A field may be plowed in this way as much as ten or twenty times before the crop is finally put in. This is believed to cause considerable nitrogen fixation by azotifying organisms.

The cane yields obtained by these agricultural methods are very low. Exact figures are not readily available, but the yields are probably lower than those obtained in the other important cane sugar countries.

Philippines: There has been more work done on the soils of Negros than any other island of the Philippine group. This island also produces the greater portion of the cane crop. The soils of the western portion of Negros are derived from volcanic lavas, while in the eastern part of the island they have been formed from limestone.

It is only recently that fertilizers have been used in the Philippines. A number of series of experiments have been carried out and all have shown a notable increase from nitrogenous fertilizers. Very little gain has been obtained from either potash or phosphates. The principal nitrogenous fertilizer now employed is ammonium sulfate. Most of the mixed fertilizers which are being applied contain potash and phosphates, as well as nitrogen. These complete mixtures are being put on as crop insurance, in the absence of more extended experiments to show whether potash and phosphates may sometimes be required.

The best yields obtained in Negros will average about one and three-quarter tons of sugar per acre, for a twelve months crop.

Hawaii: The soils of the Hawaiian Islands are almost entirely volcanic. They are derived from a limited group of rocks, the so-called basaltic lavas. The characteristics of these rocks are: a comparatively low content of silica, a high content of iron and aluminum, and a considerable content of calcium and magnesium. The soils formed from these materials have largely been weathered in place and are nearly all residual soils. There are very limited areas of alluvial soils such as are commonly found in the great valleys of the mainland of the United States.

In texture, the Hawaiian soils tend towards the heavier types, loams, silt loams, clay loams, and clays. It should be explained that there are no true clays formed of potassium aluminum silicate, in the Island soils. The clay-like materials consist of the hydrated oxides of iron and aluminum. This gives a light soil of comparatively low specific gravity. The result is a spongy open texture which allows heavy rain to percolate through the soil with ease. There is very little tendency for such a soil to puddle or pack down. We never have any plow sole or hard pan formed in the Island fields.

It was formerly believed that exact deductions as to fertilizer requirements could be drawn from determinations of the plant food present in soils. Later work has shown the great variability of composition which exists in most soils. This has caused many investigators to feel that all such determinations are valueless. With the modern work that has been done in plant nutrition, we have come to feel that the one thing we can draw deductions from is an actual deficiency in any important limiting plant food.

Extensive work has been carried out at this Station upon the soils of the various experimental areas located in the different islands of the group. Part of these soils responded to either potash or phosphate fertilization, and part of them were evidently well supplied with both these constituents. The result of this work was to show that chemical determinations could indicate the soils which were most likely to require potash and phosphate fertilization. Such work is likely to be an excellent basis for the location of carefully planned field trials. The information given by such trials is probably the best basis for fertilizer practice.

Besides work on the composition of typical soils, extensive work has been carried on in Hawaii upon the effect of fertilizers upon the soil. No noticeable increase in alkalinity of the soil or harmful effect from the heavy applications of fertilizers have been detected. Investigations have also been made on the influence of slightly saline irrigation waters.

At the present time, the principal chemical investigation at this Station is a study of the factors underlying the occurrence of root-rot. We are studying the relation of occasional accumulations of salt and the occurrence of high acidity to the susceptibility of varieties like Lahaina cane to root troubles.

In considering fertilizers for sugar cane in Hawaii, we may say there is practically always a response to nitrogenous fertilizers. The one exception to this statement is Grove Farm Plantation on Kauai. Owing to the cane area available on this plantation, it is customary to fallow the fields for about three years before replanting. The cover crop used is either the native wild legumes or pigeon peas. On the plant crop following this fallow period, no response is obtained to applications of nitrogen.

The amount of fertilizer used in the different districts in the Hawaiian group varies with the size of the crop that is ordinarily obtained. The field experiments of the Agricultural Department of this Station have helped to establish the profitable limits of fertilization in each section.

A large part of the plantations are using either complete fertilizers or mixtures which include several forms of nitrogen in combination with phosphoric acid. A portion of these plantations are only putting on potash and phosphates as a matter of insurance. We have one definite region which does give a response to potash in addition to nitrogen. This region is along the Hilo coast. Some of the fields at Ewa have shown a response to potash. There have been a few experiments in other districts where there appears to be a response to potash. There is, however, no uniform widespread need of potash.

Experiments with phosphates have shown that there is a need for phosphates on a number of plantations. This is especially true of the upper fields in portions of Kauai, Maui, and Oahu.

The Hawaiian system of heavy fertilization is designed to obtain the maximum sugar production from the limited areas of land available for sugar planting. The Island soils appear well adapted to this agricultural practice. It may also be stated conservatively that there is no present evidence of any decrease in productivity from continuous cropping to sugar cane.

Uba Hybrids

U-D 65, A Hybrid of Uba and D 1135. Propagation of 1924.

U-H 4, A Hybrid of Uba and H 109. Propagation of 1924.

Lahaina Disease, Root-Rot or Plant Failure

By W. T. McGeorge.

When the Lahaina variety first began to fail it was the general opinion that a pathogenic disease was making inroads upon this variety. Assuming a specific organism as the primary cause, the malady became known as Lahaina disease in view of the observations that the other varieties appeared to be more or less immune. Later, upon noting the same characteristics in diseased cane of other varieties in certain sections of the islands, a broader term, namely, root-rot, was adopted. The question now arises as to whether even this latter term is sufficiently broad to cover the problem which we now recognize in the failure of Lahaina and other varieties in certain sections of the islands and on a number of different soil types.

About two years ago the chemistry department undertook a study of the soil conditions associated with the infertility of some plantation soil types with special reference to those on which the Lahaina variety had failed and where other varieties were showing symptoms of so-called root-rot. In view of the presence of the most aggravated cases upon the Kauai uplands, which are composed mostly of acid types, the presence of acid salts of aluminum was suspected. The acid salts of this element have been found to be closely associated with the low fertility of many mainland soils and the problem is being intensively studied by a number of investigators at several experiment stations in the United States and Europe.

Our experiments have demonstrated beyond a doubt the toxicity of the salts of aluminum toward sugar cane and their presence in island soils. On the other hand their presence is limited to soils above a definite degree of hydrogen ion concentration or acidity. This latter point we have also proven beyond question.

Now, in casually surveying the past observations on the Lahaina failure, it was necessary to recognize the wide variety of soil types and environment in which root-rot prevails. Beginning with the Hilo-Olaa district, where Lahaina first failed, we find soil acidity with soluble iron and aluminum salts present associated with a deficiency of potash. At Honokaa we also have acid soils but fairly well supplied with both potash and phosphate. On Oahu we have root-rot on the Kaneohe soils of high acidity with deficiencies of both potash and phosphate. On the low, poorly drained fields of the irrigated plantations the soils are slightly acid or slightly alkaline, contain no acid salts of aluminum but show unmistakable evidence of saline accumulations from the irrigation water, the concentration of the soil solution depending upon such factors as seasonal rainfall, height of water table, etc. On Kauai we find root-rot in the upland soils which are high in acidity, deficient in phosphate and often in potash also. It may also not be amiss to mention a condition of H 109 on Oahu plantation diagnosed as root-rot which proved to be induced by a plant food deficiency. So much for soil types.

On reviewing the history of the disease in several of the island districts here wide variations are again noted. In the Hilo district the failure was rapid. On

the lower fields of the irrigated plantations the condition was accumulative and showed notable seasonal variation while on contiguous well drained fields Lahaina is still making good growth.

While fungi or other organisms have always been found present in the rotted roots by the pathologists, failure to discover a primary causal fungus led Dr. Lyon in 1915 to make the following statement:

> This little experiment would seem to effectively eliminate senility and parasitic organisms as plausible explanations for the "Lahaina disease" and at the same time it indicates that the trouble lies in the soil. * * *

At this time further attempts to discover a toxic condition in the soil or a soil treatment which would correct this apparent infertility having failed, the problem was again taken up by the pathologists. In spite of some extremely intensive investigations, here again attempts to find a causal fungus failed, although the presence of associated fungi was clearly demonstrated. It is obvious from the above that we were forced to assume the association of the fungus as a secondary factor only; that some other agent resident in the soil was the primary factor, and that this latter was predisposing the plant to the invasion of the fungus, in other words, lowering the vitality of the plant sufficient to permit the invasion of the organism. Reviewing the conditions previously mentioned we have to date evidence of a number of primary factors, namely, soluble salts of aluminum and ferrous iron, plant food deficiencies, saline accumulations which might act either as toxic agents or produce a variety of nutritional disturbances, and I might also safely add poor aeration or physical soil conditions.

The foregoing was the status of our investigations in April when the writer visited a number of experiment stations on the mainland where root-rot studies are being conducted. It is of interest to compare our observations with the progress of some of these stations particularly at Indiana and discuss their discoveries as applied to our own local problem.

Dr. G. N. Hoffer, at the Indiana Experiment Station, who has probably given this subject more intensive study than any other investigator, divides plant growth environment into three zones: health, susceptibility, and toxicity. The following will more clearly illustrate his method of classification:

Zone of Health:

Optimum environment for normal plant growth.

Zone of Susceptibility:*

Subtoxic concentrations of aluminum or other toxic agent.

Partial plant food deficiencies.

Association of fungus or other organism with these agents.

Zone of Toxicity:*

Toxic concentrations of aluminum or other toxic agent.

Notable deficiencies of plant food.

(The association of an organism is not necessary for plant failure in this zone although usually present.)

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* It is my interpretation that he places no limit to the factors which may be present in the zones of susceptibility and toxicity. Poor physical condition of the soil and factors productive of abnormal nutritional disturbances might be included. Temperature, also, can be a factor.

Of the healthy zone no further explanation is necessary. It simply includes the environment under which the plant makes normal growth. Inhibiting factors are entirely absent or inactive.

In the zone of toxicity there is present sufficient concentration of aluminum (this one factor is given merely to typify a condition) to cause a serious stunting of the plant or death itself regardless of whether a fungus or other organism is present.

Within the zone of susceptibility most soil fertility problems arise. There is in this zone an environment productive of sufficient loss of plant vitality to predispose the plant to the invasion of many organisms. Taking aluminum again as an example, there will be present in the susceptible zone a concentration which of itself may not seriously stunt the growth of the plant, although its effect may be apparent. But in the presence of many fungi the organism, taking advantage of the lowered vitality of the plant, becomes, through invasion of the tissues, a secondary factor. The condition known as root-rot will follow. The same line of reasoning obtains for a plant food deficiency and Dr. Hoffer has demonstrated the above conclusively in many experiments. In simpler terms the fungus or secondary factor is "the straw that broke the camel's back."

Applying the above line of reasoning to our observations on sugar cane some very significant correlations are noted and a number of inconsistencies clarified.

Let us first consider Dr. Lyon's experiment in 1915, in which he transferred a sick Lahaina stool to our Experiment Station soil and obtained a complete recovery of the plant. In making this transfer he carried the secondary factor (the fungus) into the good soil in which the primary factor was absent. Leaving behind the primary factor the plant recovered on failure of the secondary factor to "play its role" effectively in the absence of the primary predisposing agent. This same line of reasoning applies in the recent experiments of Mr. Lee in which he obtained renewed growth on transferring "sick" stools from Puunene fields to the Experiment Station soil.

Now let us refer in the same manner to Mr. Carpenter's investigation of the pythium fungus. On sterilizing the soil, thereby removing the secondary factor (the fungus), he improved plant growth. That is, the primary factor (toxic agent) being present only in subtoxic concentration, he thus obtained better growth, although not absolutely normal in all cases. On reinoculating the sterilized "sick" soil; thereby obtaining again the association of both primary and secondary factors, he was able to produce the root-rot as it existed in the soil originally. He also improved root growth in pots by the use of Qua Sul and copper sulphate. It is entirely fair to assume here also that the improved growth obtained by the above treatments was due to their fungicidal properties and control of the secondary factor. Inability to completely control the fungus by the above fungicides in the field, as was possible in pots, will explain the failure of the above on a field scale. Mr. Carpenter's work clearly demonstrates the *association* of the pythium type fungus with the so-called root-rot.

Merely as illustrating the point at issue we may even proceed further in applying Dr. Hoffer's classification. For example, in eye-spot there are certain climatic factors which predispose the cane to invasion of the fungus. In view

of this essential climatic environment is it not fair to classify the climatic factor as primary and in a like manner the red stripe disease which attacks primarily the Tip canes. Is it not fair to assume some inherent characteristic of the variety as predisposing these canes to invasion? While these allusions are far removed from the chemical factors which we find predisposing the cane to so-called root-rot they well illustrate the logical line of reasoning which Dr. Hoffer is applying so successfully in his root-rot investigations on corn.

In his physiological examinations he has noted certain characteristic differences between normal corn plants and those which have become severely root-rotted. Namely, that the vascular plate tissues in the nodes of the stalk are discolored and in various stages of disintegration. Qualitative and quantitative tests for iron and aluminum have shown abnormal accumulations of these elements at the nodal joints. This accumulation, usually, is also associated with a stunted condition when the inhibiting agent is other than soluble iron and aluminum salts in the soil.

In examining cane stalks grown on acid soils at Olaa and Honokaa we have found these same characteristics in sugar cane. Also in examining the short internodal winter growth of cane stalks we have found these nodal accumulations.

Dr. Hoffer believes that this disintegration of the nodal vascular plate tissues precedes the rotting of the plant roots. In other words, the channels of food transmission are cut off, resulting in a general failure of the plant. Root-rot thus becomes a more complex problem and one of plant failure rather than root-rot alone.

Further facts which might throw some light upon the comparative resistance of cane varieties were gathered at the Rhode Island Experiment Station. It has been suspected that there might be some variation in the nutritional requirements of Lahaina and other varieties as well as differences in their foraging properties and powers of selection or rejection of mineral salts in the soil solution. The Rhode Island Station in studying the root-rot problem has included a wide variety of crops. They have found that the carrot has a remarkably constant mineral composition regardless of the soil environment under which it is grown. Its inherent powers of resistance are also high. On the other hand, lettuce, onions and some other crops included in their studies show a wide variation in mineral composition when grown under different soil conditions and a low degree of resistance. In other words, the selective power of the plant or its foraging power appear to be closely related to degree of resistance.

Summary

The above is offered as a comparison of our root-rot problem with the results being obtained in similar investigations on the mainland. The complex nature of the problem becomes more evident as progress is made and appears as one of greater breadth than implied in the term root-rot. We often note characteristic symptoms in the tops as well as the roots. These include premature dying of the lower leaves and their greater tenacity to the stalk. The preliminary symptoms of malnutrition are also evident, as are also indications of a moisture

deficiency. These include stunted top growth, less stooling and dying or curling of the leaf tips. Our problem is therefore one of general plant failure under a number of conditions of infertility. Lahaina cane being a susceptible variety adapted to a narrow range of conditions has prompted the term "Lahaina disease," but it now becomes evident that the failure of this variety is only one phase of a larger problem.

Prevention of Mold in Polariscope*

By Herbert S. Walker.

One of the minor problems encountered in a tropical sugar factory is the difficulty of keeping polariscopes in good condition. During damp weather the Nicol prisms and quartz wedges become infected with a mold growth which, unless removed, etches into their polished surfaces and eventually ruins them for accurate work.

Heretofore the only remedy has been to take the instrument apart occasionally and wipe off the optical parts. This is a rather troublesome operation since it generally means readjustment of the scale, and, unless done by an expert, may cause serious damage to the delicate prisms.

During the past season we have been experimenting with thymol as a mold preventive, with very promising results. The polariscope is disassembled, cleaned and a few crystals of thymol inserted in the compartments at each end of the polarizing and analyzing Nicols and in the bottom of the brass case which covers the wedge mechanism. The polariscopes at two of our centrals were thus treated early this season and have stood for more than six months without any sign of mold growth, although it had formerly been necessary at one of these factories to clean off the prisms every two weeks. Polariscopes not treated with thymol all showed some damage from mold when opened up at the end of the grinding season.

Since thymol is slowly volatile, one treatment will not last indefinitely, but as long as the odor persists the instrument is probably safe. Present indications are that the antiseptic will not have to be renewed more than once or twice a year.

Some Sugar Cane Growth Measurements

By H. K. Stender.

[In 1922, after reading of the exceptional cane growth secured by Dr. Mario Calvino, and associates, at the Cuban Experiment Station, from widely spaced single-eye plants of sugar cane, started first in small boxes and afterwards placed

* Sugar News, Vol. 5, No. 8.

in deep holes, well nurtured and amply supplied with water, we decided to conduct a similar test in the forced feeding of cane. We used some selected progenies to have whatever advantage of yield that this might lend.

The detailed yields were reported in the *Record* for July, 1924, by A. D. Shamel.

In order to study the seasonal growth of cane independently of irregularities and deficiencies in nitrogen and irrigation, we started in August, 1922, systematic

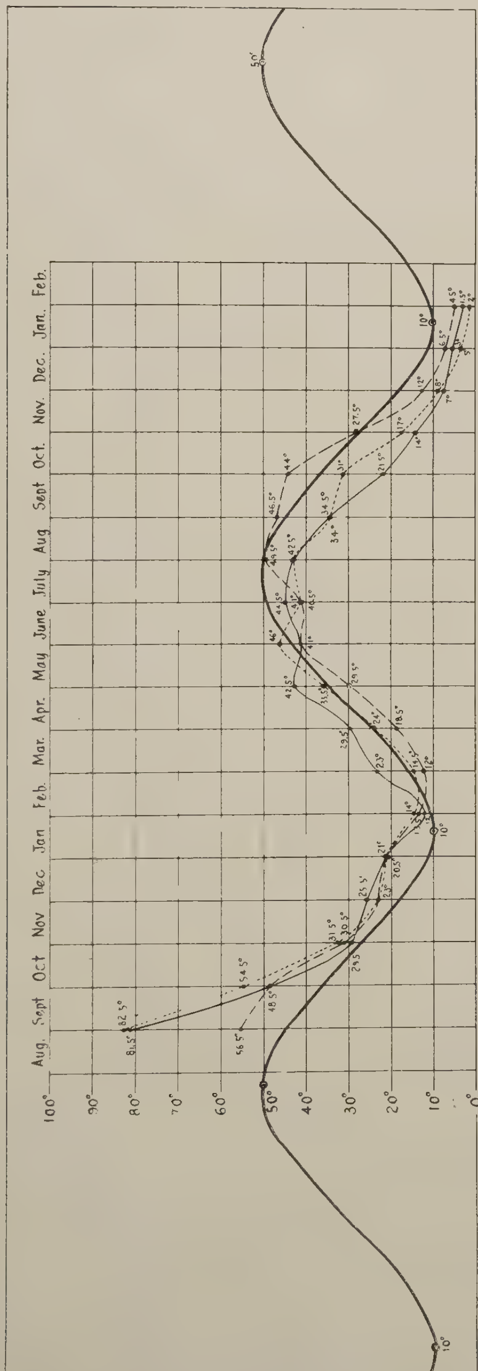

Fig. 1. The heavy line extending across the diagram is the curve of potential cane growth suggested in the 1923 annual report of the Experiment Station. (It is based on the hours of daylight offset by twenty-eight days.) Plotted against that curve are the average growth measurements from six representative stalks of cane grown under prime conditions of fertilization and irrigation, so that the growth would reflect that difference due to heat and light and the age of the cane. The measurements are shown in three ways: length of stalk, volume of stalk, and weight of stalk (the last two were taken after harvesting). The solid line (———) represents weight, the dotted line (........) volume, the dashes (— — —) elongation. These measurements were converted to growth degrees, mathematically, and plotted accordingly. It will be noted that the weight curve shows 81.5 growth degrees for August, 1922, instead of the theoretical 50; but in August, 1923, a second season growth of 42.5°. In general, the second season growth falls much below the first season growth, giving additional evidence in favor of the idea of producing two crops of cane in three years.

measurements of a number of stalks in this plot. The details of this phase of the work were handled by H. K. Stender, under the direction of J. A. Verret, and are recorded here by notes, diagrams, and photographs.

In order to study the relationship of measured cane growth to the curve of potential cane growth proposed and illustrated in the annual report of the Experiment Station for 1923, whereby July growth was assumed to be five times that of January growth, Mr. Stender has reduced his measurements to a percentage growth-degree basis and has plotted them upon the proposed curve of potential cane growth as shown on Fig. 1, page 473. From his diagram we see that the theoretical curve does not exaggerate the difference in seasonal growth actually secured in this cane, but in fact falls short of it.—H. P. A.]

Location: The plot is located on the Experiment Station grounds in the west section of Makiki Field 7.

Planting: Single-eye, three-joint cuttings (two eyes having been gouged out) of the various progenies of H 109 were planted in small germinating boxes on April 8, 1922. On May 25, 1922, the young plants were transplanted to holes that had been dug in Field 7. These holes were 1½ ft. x 1½ ft. square, by 1½ ft. deep, and spaced 5 feet from center to center.

Irrigation: The irrigation of the cane in this plot was done with a garden hose. For the first month and a half, May 26 to July 6, 1922, a one-inch irrigation was applied semi-weekly; for one month after this, July 10 to August 4, 1922, a two-inch irrigation was applied semi-weekly, then for a period of nine months, August 8, 1922, to May 8, 1923, four inches was applied semi-weekly. Rain was taken into consideration during the winter months in that no water was applied whenever the rainfall was sufficient to keep the ground thoroughly moist, and at times water was applied to make up the difference whenever the rainfall was not sufficient to amount to a four-inch irrigation. For the remainder of the growing time, a period of seven months, a six-inch irrigation was applied semi-weekly. The idea was to keep the ground thoroughly moist so that at no time would the cane suffer from a shortage of moisture.

A detailed record of irrigation is recorded below:

Cane planted 5/25/22.
5/26/22 to 7/6/22 1" irrigation semi-weekly.
7/10/22 to 8/4/22 2" irrigation semi-weekly.
8/ 8/22 to 5/8/23 4" irrigation semi-weekly. Rain considered.
5/12/23 to 12/6/23 6" irrigation semi-weekly.
Cane harvested March 17, 1924.

At the above rate of irrigation it is evident that water was eliminated as being a possible limiting factor in the growth of the cane.

Fertilization: Starting with June 12, 1922, and at regular monthly intervals thereafter, up to and including September 12, 1923, applications of a mixture of nitrate of soda and sulphate of ammonia were applied at the rate of 100 pounds of nitrogen per acre per month. This was made up as follows: 2½ oz. of N. S. and 2½ oz. of A. S. or a total of 5 oz. of the mixture per hole. In addition to this, a mixture of stable manure and decaying trash was applied at three dif-

ferent intervals while the cane was still quite young. The first application was applied on July 24, 1922, at the rate of 3 bucketfuls per hole. The two subsequent applications were applied on August 10, 1922, and September 1, 1922, respectively, at the same rate, 3 bucketfuls per hole, for each application, making a total of 9 bucketfuls per hole.

At the above rate of fertilization it is also evident that fertilizer was eliminated as being a possible limiting factor.

Environment: This factor was largely eliminated as all the stools selected for growth measurements were inside stools and located within a small area, and yet each stool spaced enough apart to insure heavy growth.

Temperature: Fertilizer, water and environment having been reduced to a minimum as possible limiting factors, seasonal differences in growth may be attributed almost entirely to the influence of temperature and daylight.

Growth Measurements: Mr. Shamel in his article, *The Performance Records of Some Individual Sugar Cane Stools,* writes as follows: "Growth Measurements: Systematic growth measurements were carried on with stalks of selected stools in order to show the rate of growth of the plants during the different seasons throughout the course of this experiment."

Unfortunately, the idea of making growth measurements in this cane did not occur until quite some time after the puka planting experiment had started. The experiment started in April, 1922, and it was not until August 15, 1922, when the first growth measurements were made. Practically three months of the best growing time was not recorded. Had this been done, a more complete growth curve could have been constructed showing very accurate relationship between first season and second season growths for cane planted at that particular time. About 15 stools in this small area having maximum controlled conditions, excepting temperature and light, were selected for growth studies. One stick in each stool was used upon which measurements were to be made. During the course of the experiment many of them were eliminated due to various conditions that had arisen, such as: having been blown over, broken, attacked by rats, borers, termites, etc. At the end of the experiment there remained only six stalks upon which growth measurements had been made throughout the whole time, from planting to harvesting. Of these six, three stalks tasseled three months before harvesting and three stalks kept on growing at a very slow rate. An average of these six stalks was taken and used to compare with the temperature curve.

Method of Procedure: Two small stakes were driven into the ground, one on each side of a stool in which a stalk was to be measured. They were driven so that the tops were very close to the ground and quite level. A stick placed in a horizontal position on the tops of these two stakes gave a permanent level from which measurements could be made. From the intersection of the bottom of this stick and the cane stalk a measurement was made up to the last appearing joint triangle (see Fig. 2). From then on a new measurement was made every time a new joint triangle appeared, and every time a measurement was made the date was marked on the joint triangle, India ink being used.

After the leaves fell off it was an easy matter to trace back the dates from the record and identify the joint formed by any particular leaf. In this way

the rate of joint formation and cane growth is secured for any unit of time. The data were recorded as follows:

Stalk No.	Days	Date	Length	Days	Date	Length	Days	Date	Length
35	....	8/14	.96	4	8/18	1.14	4	8/22	1.37
37	....	8/14	1.00	4	8/18	1.18	5	8/23	1.46
40	....	8/14	1.30	3	8/17	1.48	4	8/21	1.67

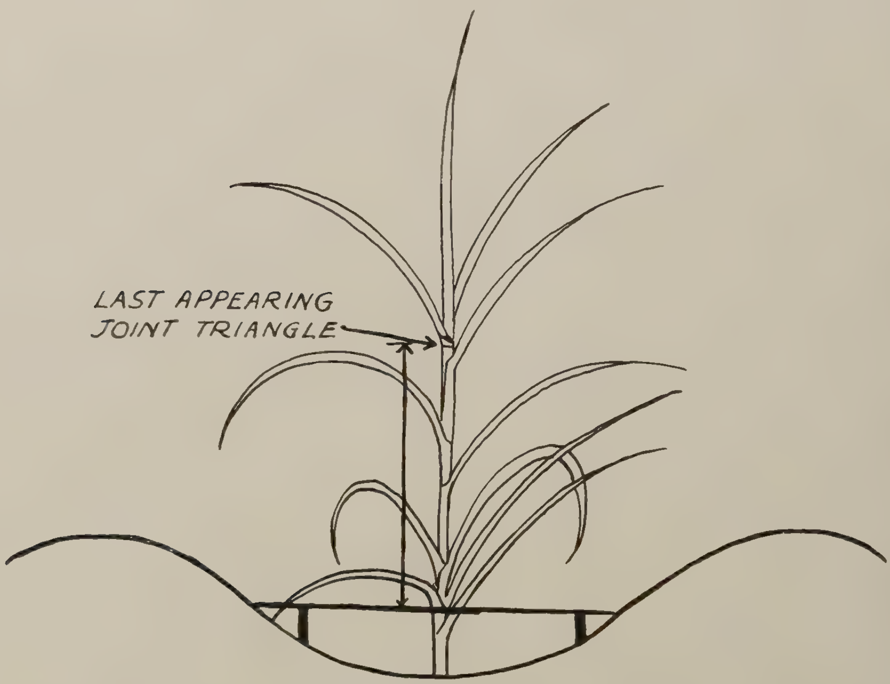

Fig. 2. Method of making growth measurements.

In order to keep up this record it was an almost daily routine of observations so that as soon as new joint triangles appeared the canes were measured and data recorded. From this data sheet, a growth curve can be constructed showing the rate of growth (elongation only) per month. This is shown in Fig. 3.

When the plot was harvested great care was taken not to break any of the stalks upon which growth measurements had been made. On each joint of each stick the date of the appearance of its corresponding joint triangle was recorded. In this way the growth for any particular period of time could be visualized.

Diameter measurements were then made on each joint and an average diameter arrived at for each month's growth. From the length per month and diameter figure for that month, volume per month was calculated. This was done for each of the six stalks and then averaged, and the average volume per month arrived at. The volume curve is shown in Fig. 4.

From the Weather Bureau of the U. S. Department of Agriculture a complete record of the average monthly temperatures covering the entire period of time during which this experiment was in progress was obtained and plotted. This is shown in Fig. 5.

Placing all of the above curves on one sheet we can picture the effect of temperature on cane growth. See Fig. 6.

Illustrations of some individual stalks are given.

Plate 1 shows the growing portion of Stalk No. 35 with dates marked on the joint triangles indicating the time when these joint triangles first appeared and measurements made. Each measurement was made from the last appearing joint triangle down to a marked point somewhere on the stalk below, which was assumed to be constant. It is not difficult to understand how, after the dry leaves have fallen off, the corresponding dates can be traced back from the recorded data and any particular joint located and marked. In this way a determination of just what section of the stalk was formed in any particular month was made possible, and a natural graph was made by cutting the stalk into sections determined by the dates on the joints and placing these sections vertically upon a horizontal plane as shown in Plate 4.

Plate 2 shows the stripped growing portion of the same stalk (Stalk No. 35) with dates marked on each joint. These dates were transposed from the leaves, and then from the recorded data dates following these were marked along the remainder of the stalk.

Plate 3 shows the entire stalk (Stalk No. 35) with monthly sections marked off. These sections were cut at the points marked and the natural graph shown in Plate 4 was made.

In studying the above photographs it becomes evident that a great saving in time, with less dead cane and very little difference in yield, would have been effected had this experiment been cut at 18 months.

Four illustrations of Stalk No. 36, giving the same information are also shown, and four others pertaining to Stalk No. 40. From these one may study the small differences of individual stalks, as well as the general similarity due to seasonal influences.

Plate 13 shows a stalk of cane harvested from this puka planting experiment upon which growth measurements had been made. This stalk is 23 feet long, not measuring the leaf portion.

Diameter Studies: In conjunction with the above investigations some studies in diameter measurements were carried on, the object being to determine whether or not cane increased or decreased in diameter after the dry leaves had fallen off. A micrometer caliper was used in this work and fairly accurate figures were obtained. This work was carried on as follows:

With a micrometer caliper the long and short diameters of each joint of each of the six stalks mentioned above were measured, starting from the dead leaf portion and going down along the stalk a year's growth, starting with the section of the stalk formed in August, 1923, and going back to the section formed in August, 1922.

The long and short diameters were averaged for each joint and the joint diameters were averaged for each month. In this way the curve shown as a smooth line in Fig. 7 was plotted. Six months later the diameters of these same canes were measured at exactly the same points where they had been measured previously. In the same way the average monthly joint diameters were arrived at and plotted. This is shown as a broken line in Fig. 7.

By studying the curves it will be noted that the differences in diameter one way or the other are so small as to be within experimental error. Hence it is to be concluded that after the dry leaves fall off there is no increase or decrease in diameter.

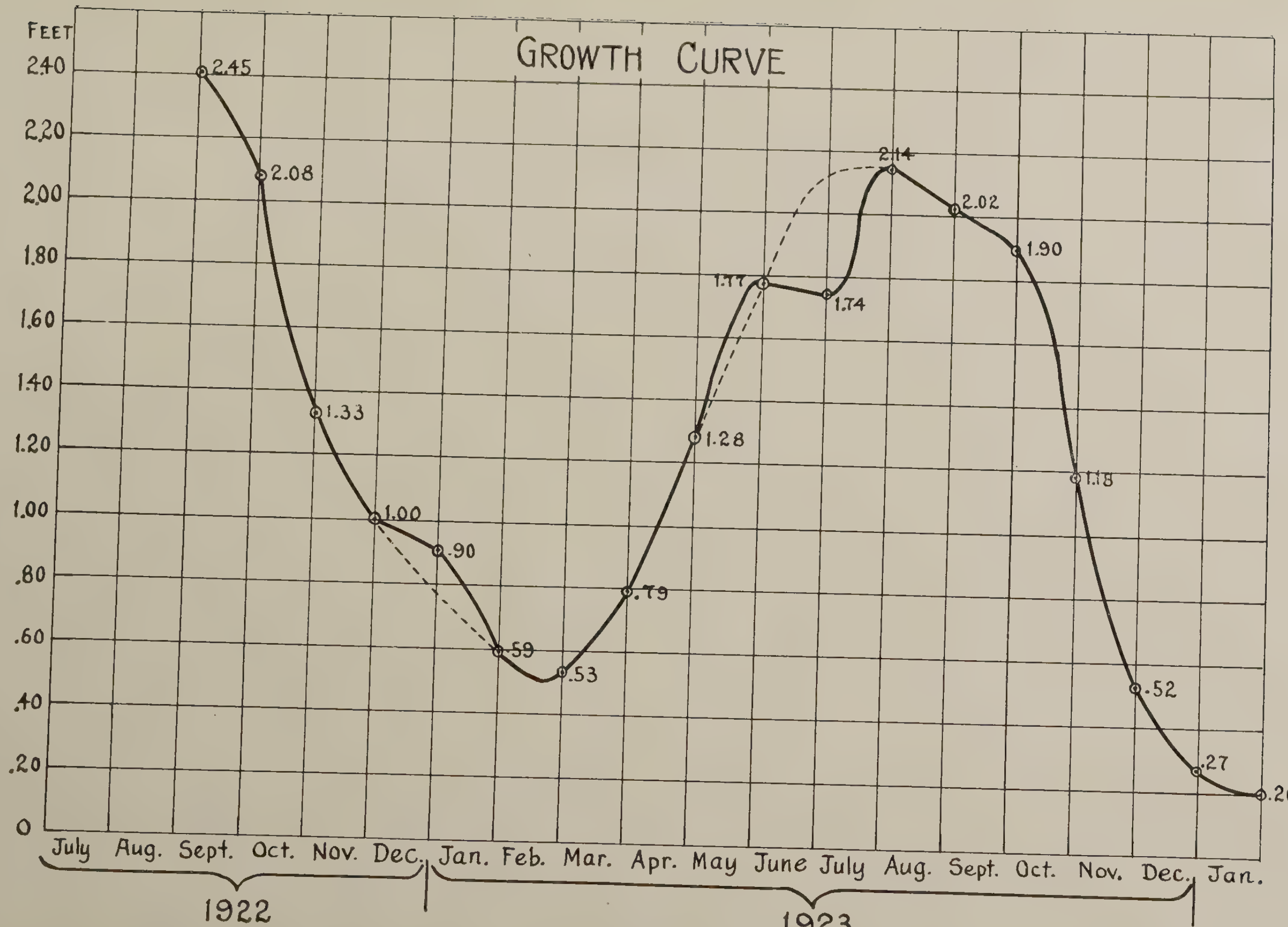

Fig. 3. Showing length per month in lineal feet. Average of six stalks of H 109 cane; planted April 8, 1922, first measurements made August 15, 1922; harvested March 17, 1924.

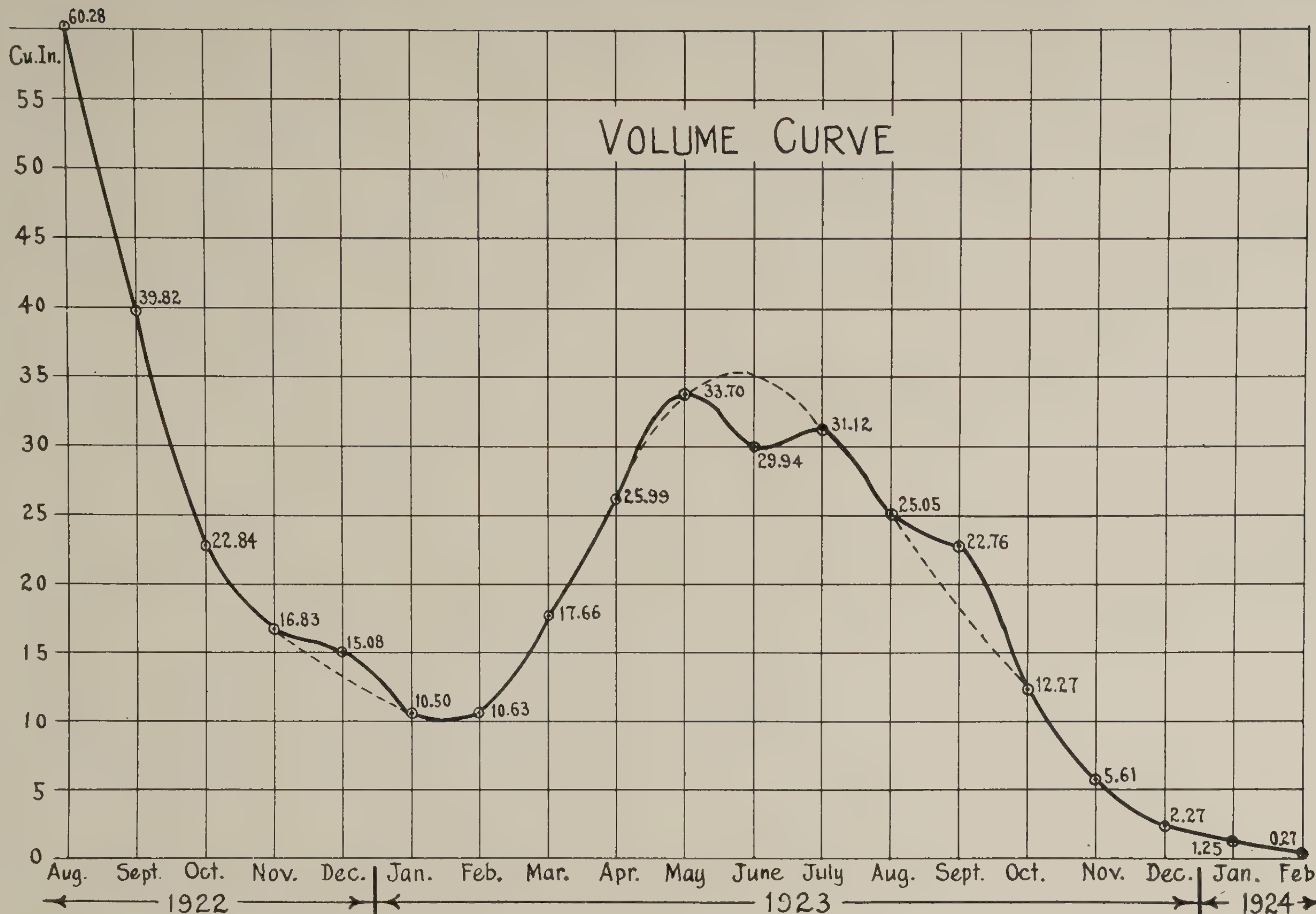

Fig. 4. Showing the volume of cane produced per month in cubic inches; average of six stalks of H 109 cane. Volume calculated from data secured on circumferences and lengths.

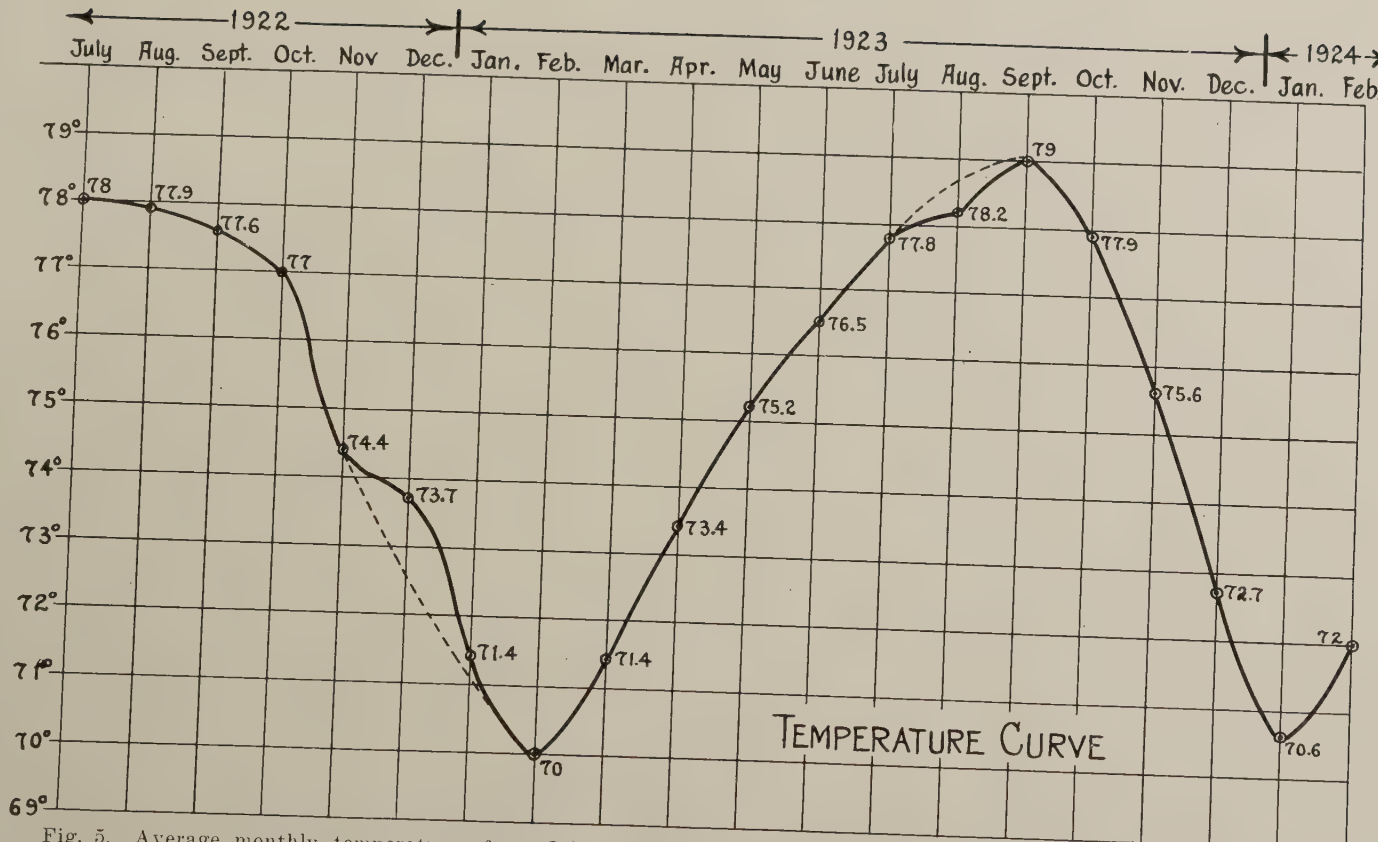

Fig. 5. Average monthly temperatures from July, 1922, to February, 1924. Taken from the Monthly Meteorological Summary of the Weather Bureau of the U. S. Department of Agriculture.

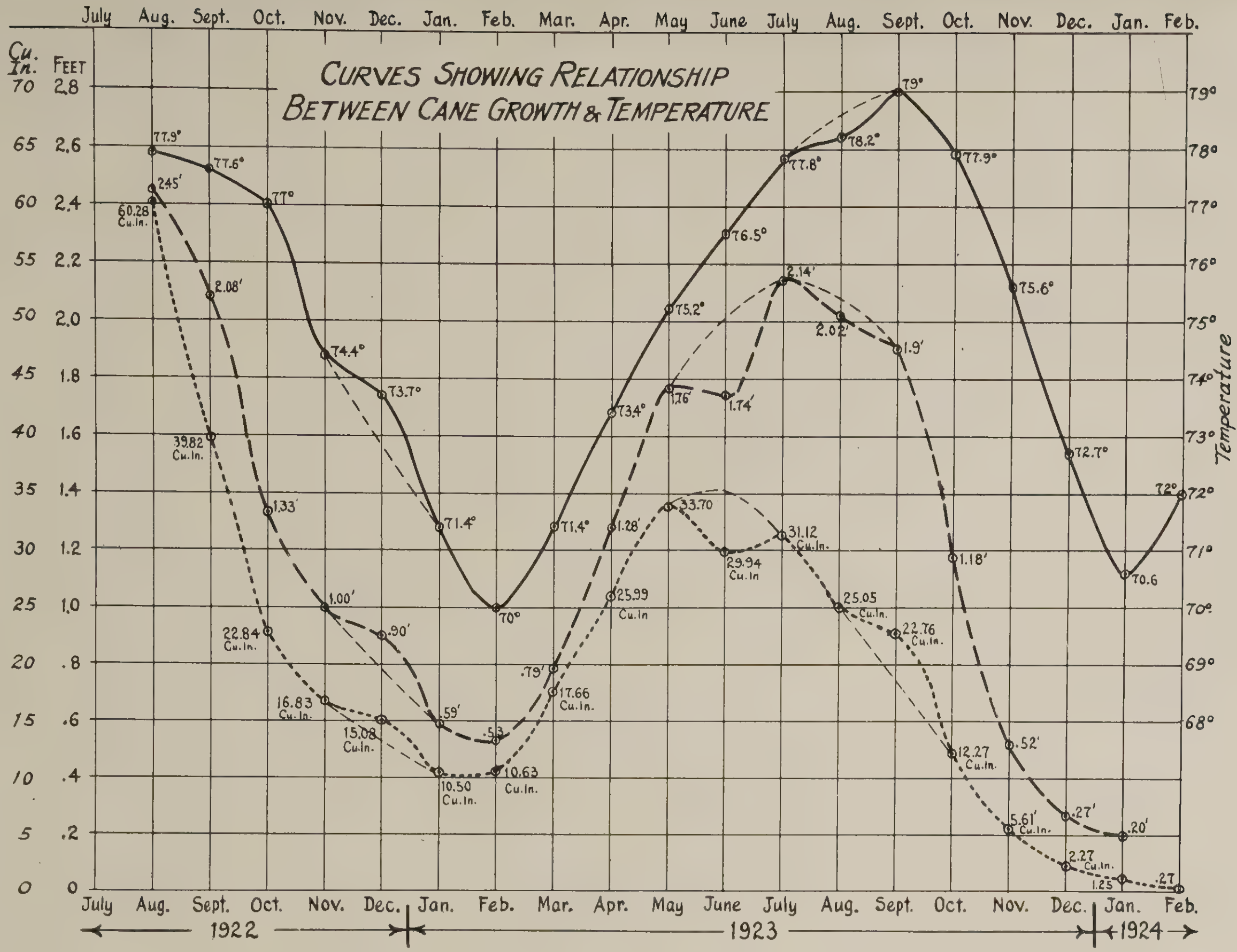

Fig. 6. The solid line (————) is the temperature curve shown in Fig. 5. The broken line (— — — —) is the growth curve shown in Fig. 3, and the dotted line (......) is the volume curve shown in Fig. 4. These curves are plotted here so as to show the effect of temperature on cane growth.

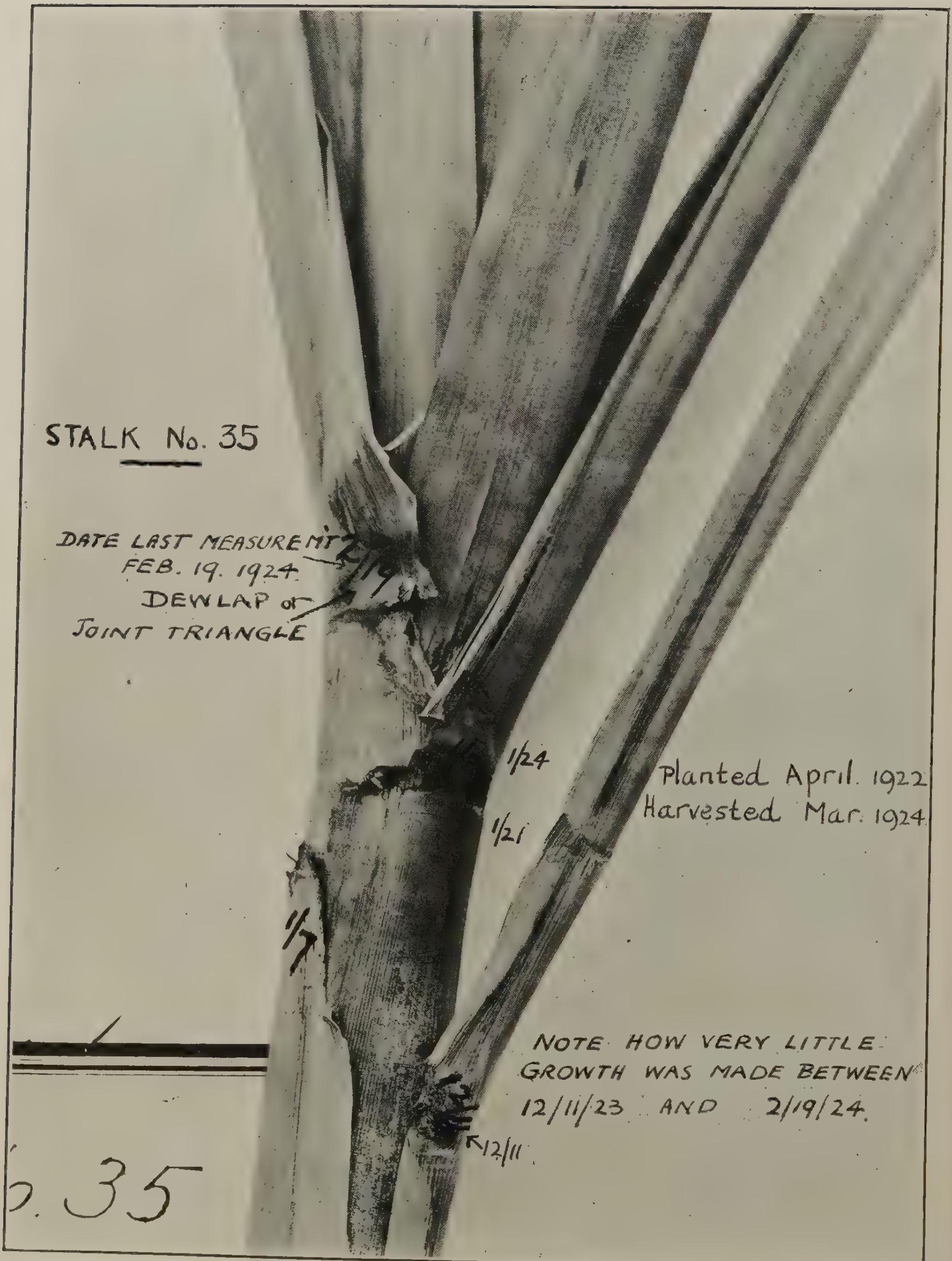

Plate 1. The top of Stalk No. 35, showing that growth had almost ceased at the end of the two-year period.

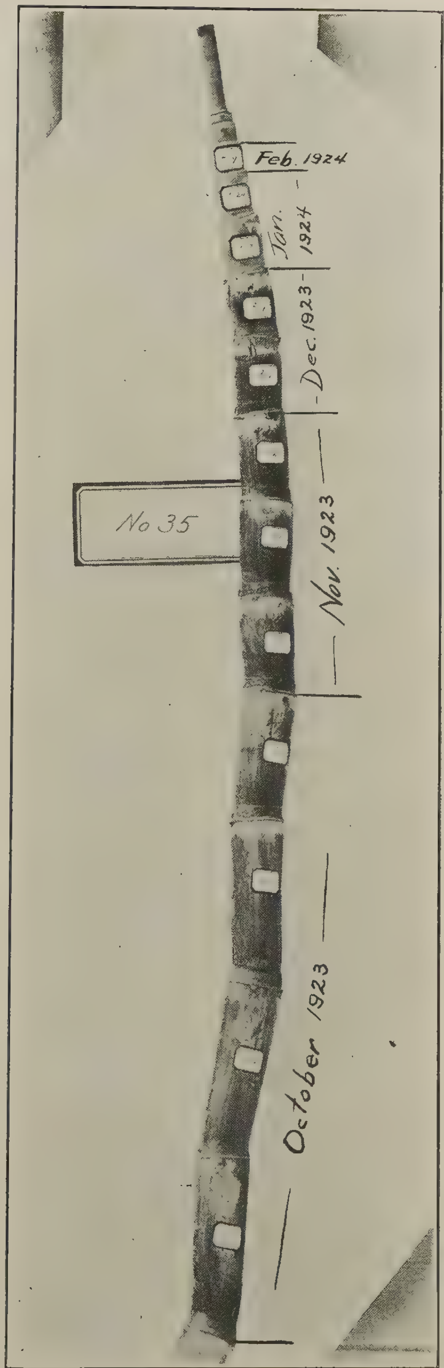

Plate 2. The top of Stalk No. 35, stripped of its leaves to show the slow rate of joint formation during the second winter of its growth.

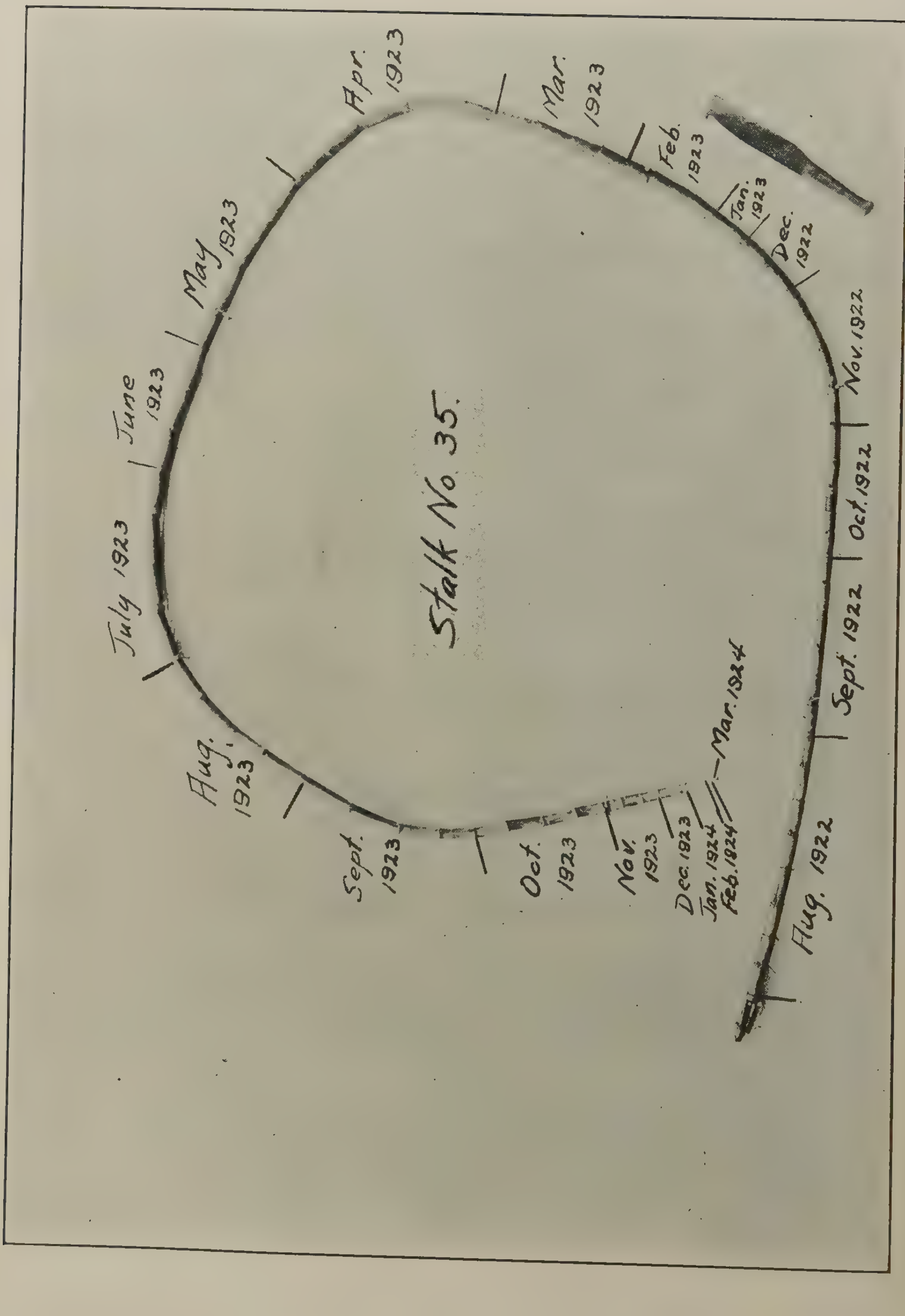

Plate 3. Stalk No. 35, marked to show the monthly growth.

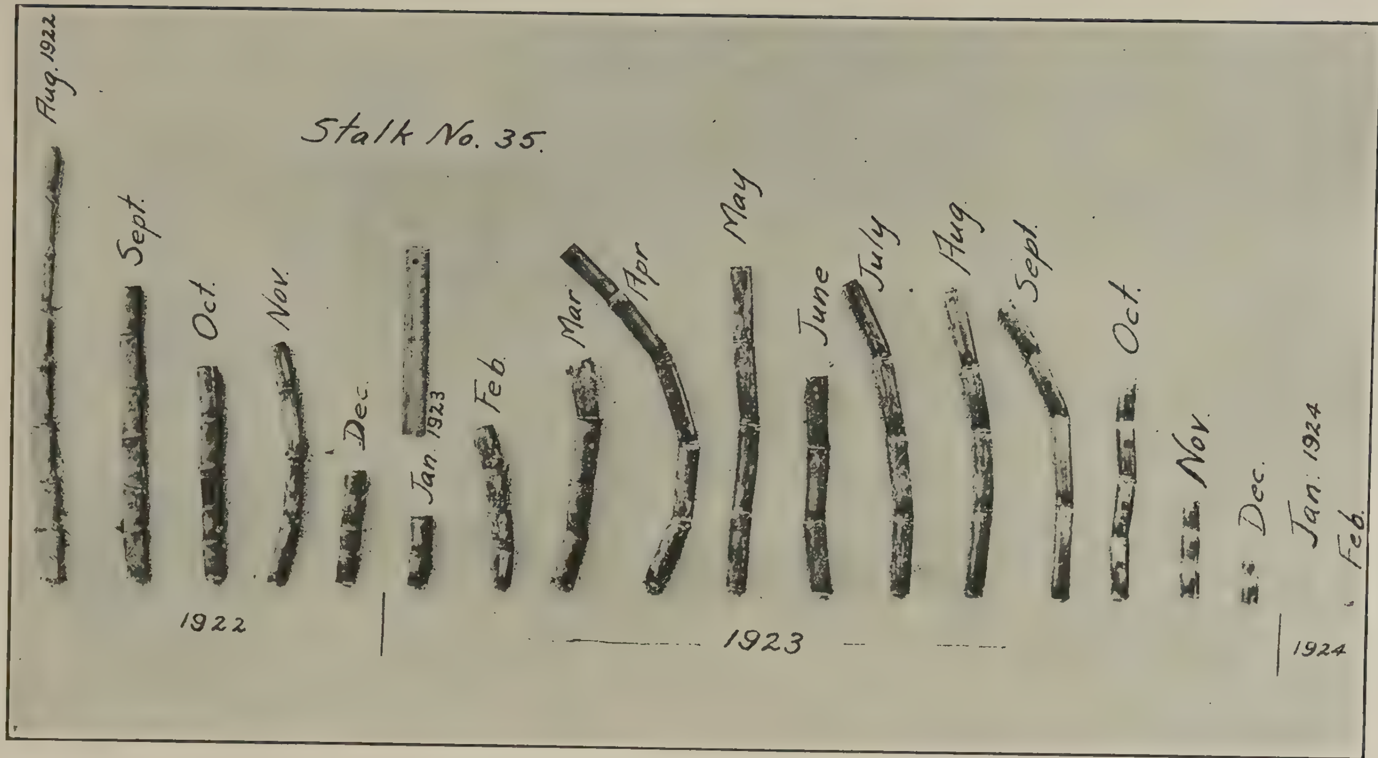

Plate 4. Stalk No. 35, as shown in the previous picture, is here cut into sections so as to get a better comparison of the growth that took place from month to month.

Plate 5. This photograph and the three that follow show the same views of Stalk No. 36 as have already been shown of Stalk No. 35, in order that the general similarity of growth can be noted together with the minor variations due to individual stalk differences.

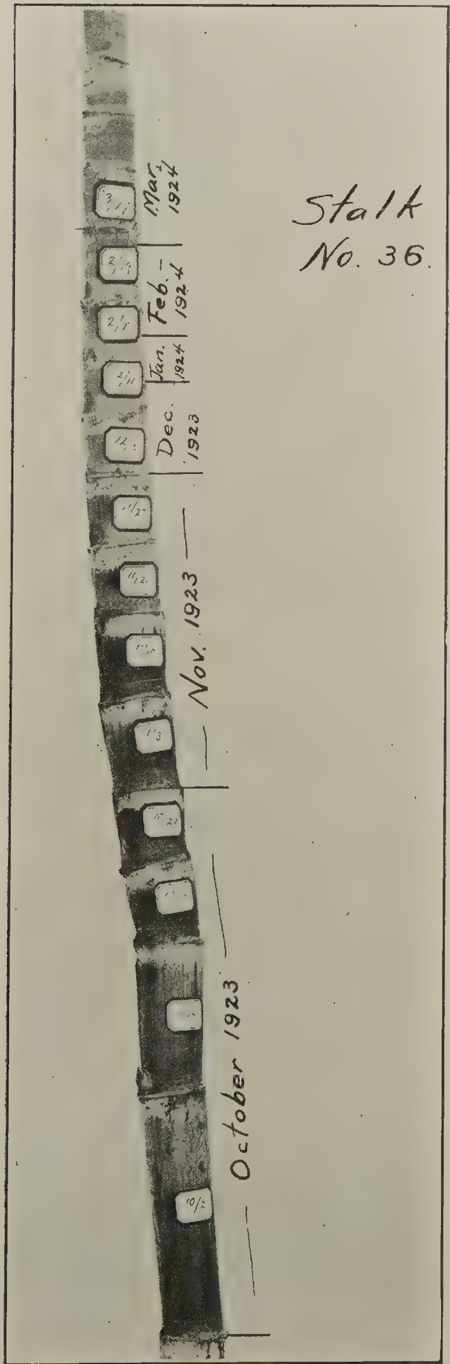

Plate 6. Stalk No. 36. Compare with similar pictures of Stalks Nos. 35 and 40.

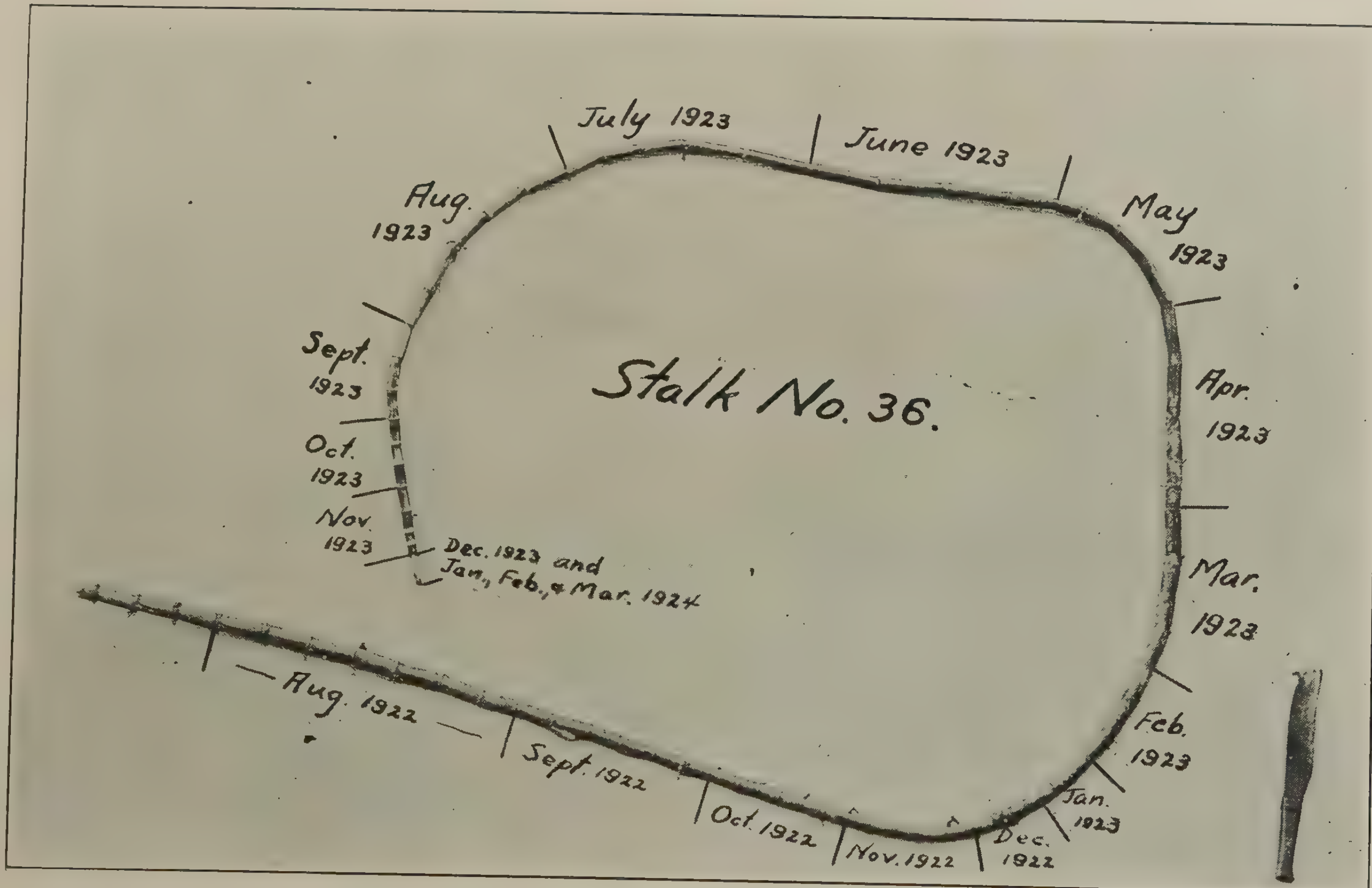

Plate 7. Stalk No. 36. Compare with similar pictures of Stalks Nos. 35 and 40.

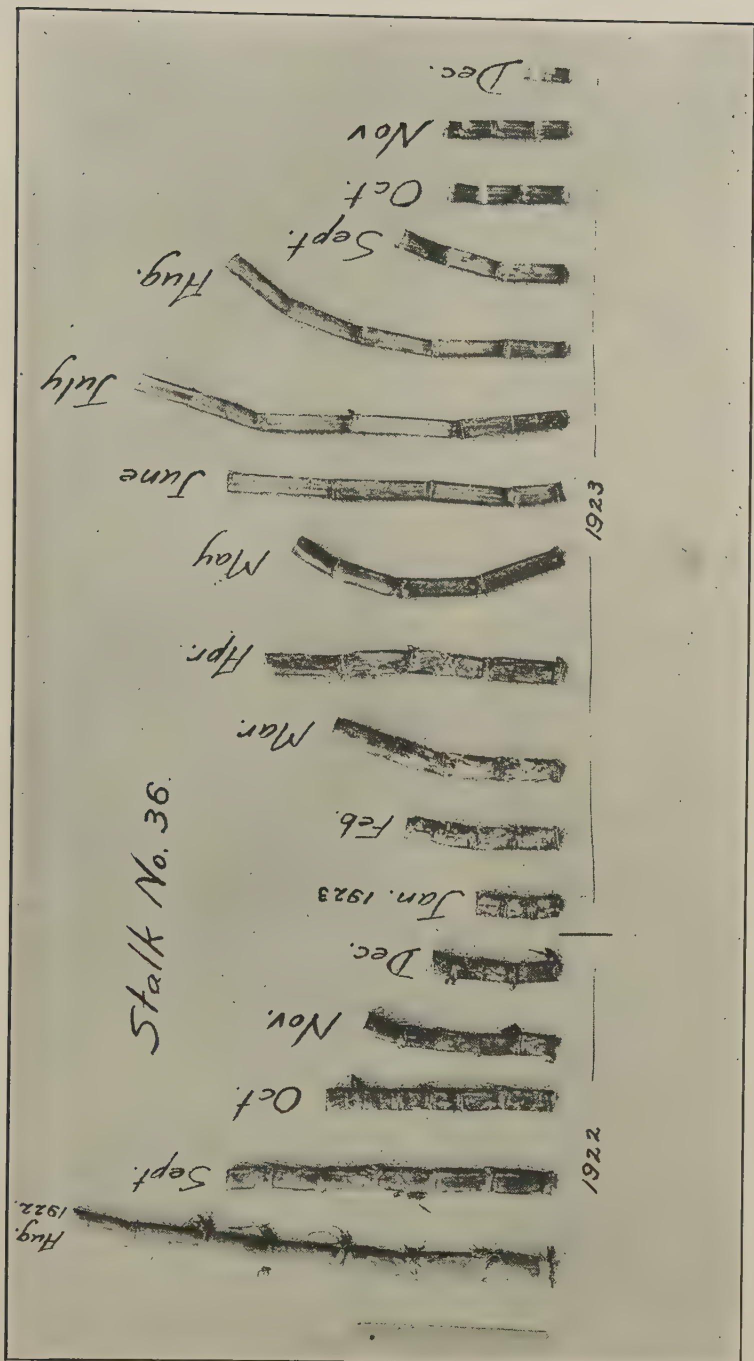

Plate 8. Stalk No. 36. Compare with similar pictures of Stalks Nos. 35 and 40.

Plate 9. Stalk No. 40. Compare with similar pictures of Stalks Nos. 35 and 36.

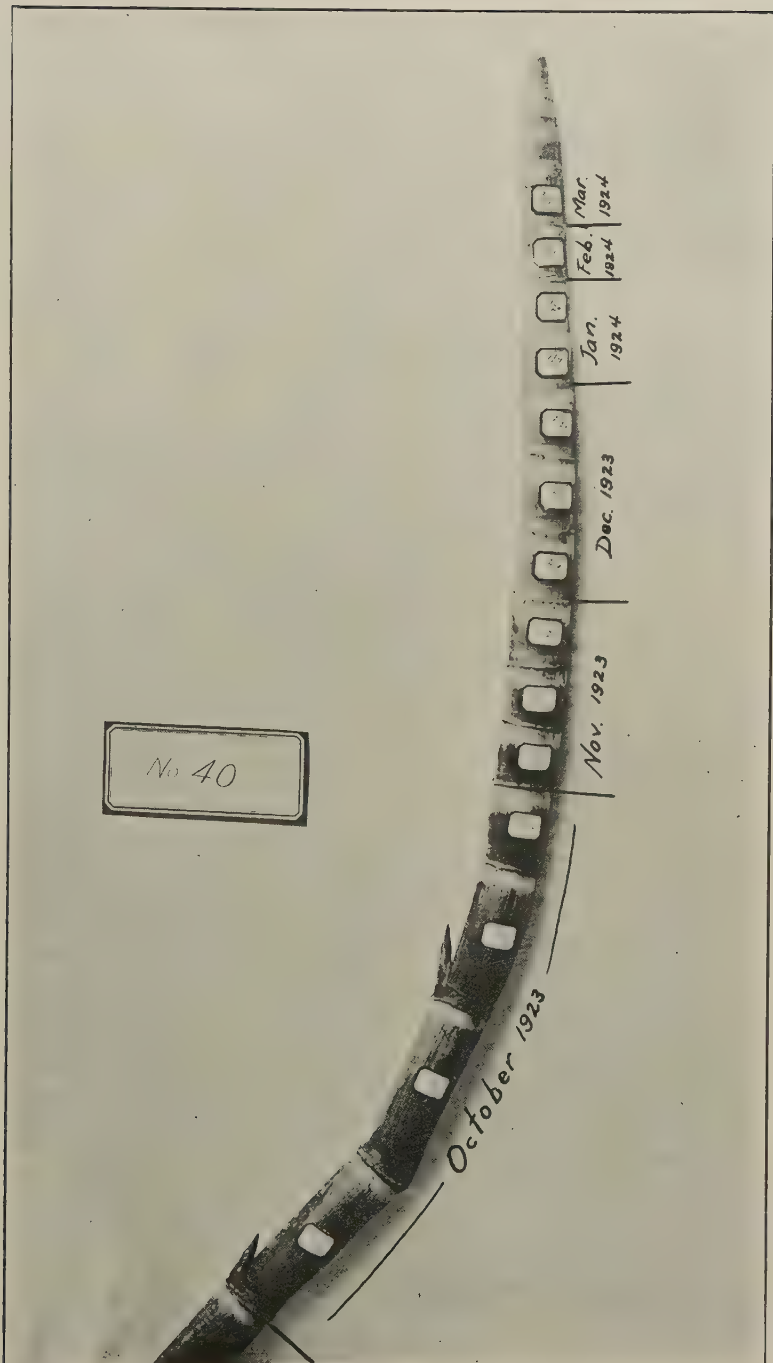

Plate 10. Stalk No. 40. Compare with similar pictures of Stalks Nos. 35 and 36.

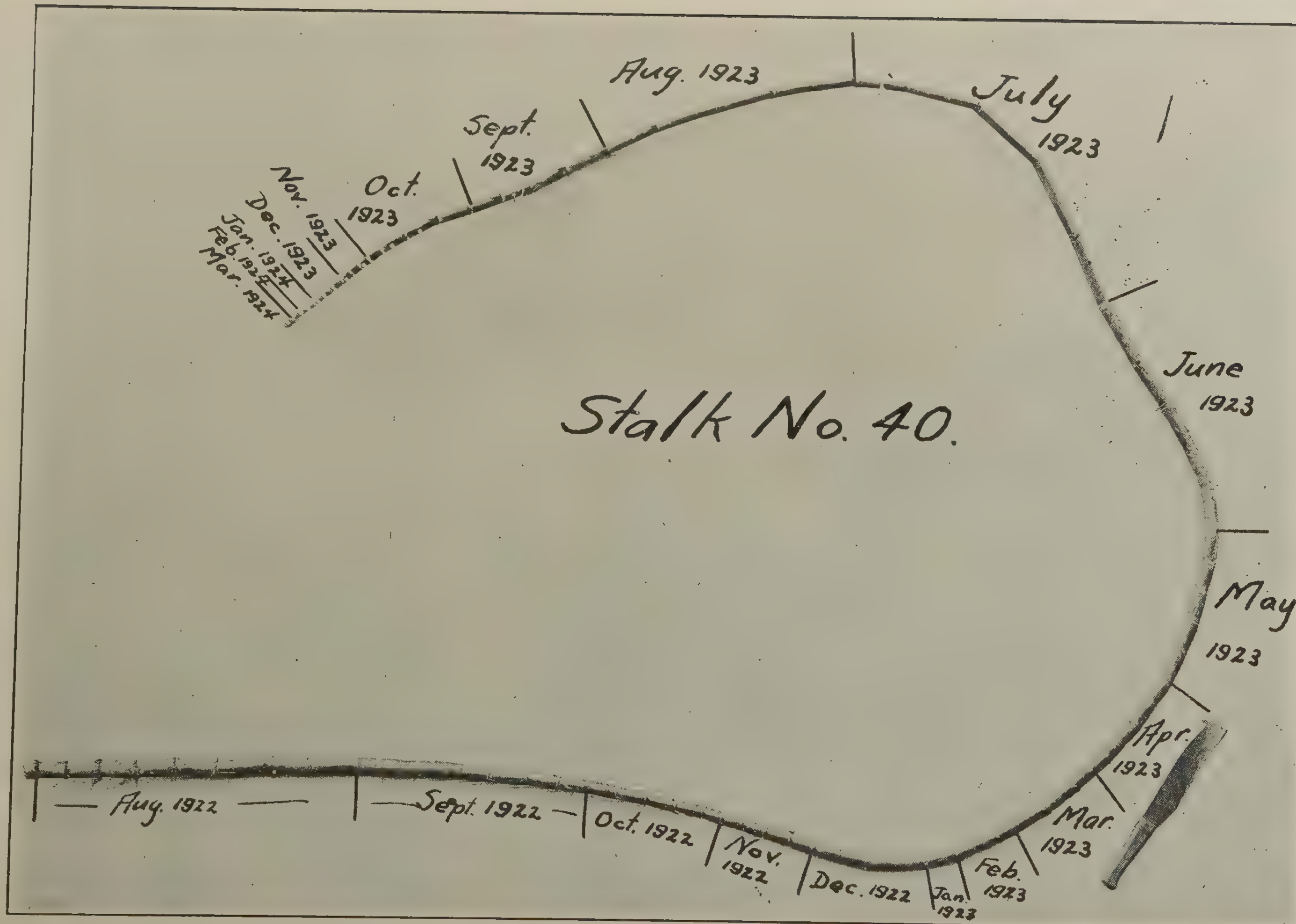

Plate 11. Stalk No. 40. Compare with similar pictures of Stalks Nos. 35 and 36.

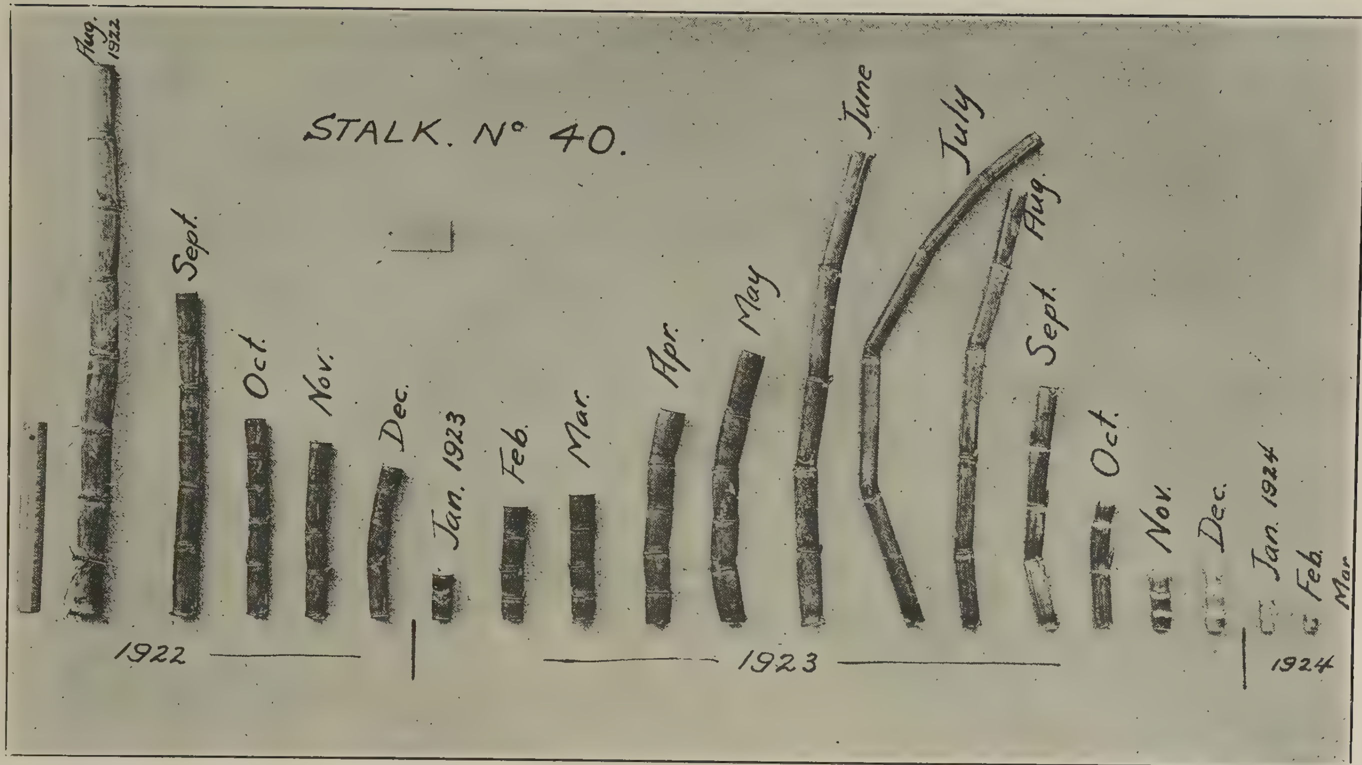

Plate 12. Stalk No. 40. Compare with similar pictures of Stalks Nos, 35 and 36.

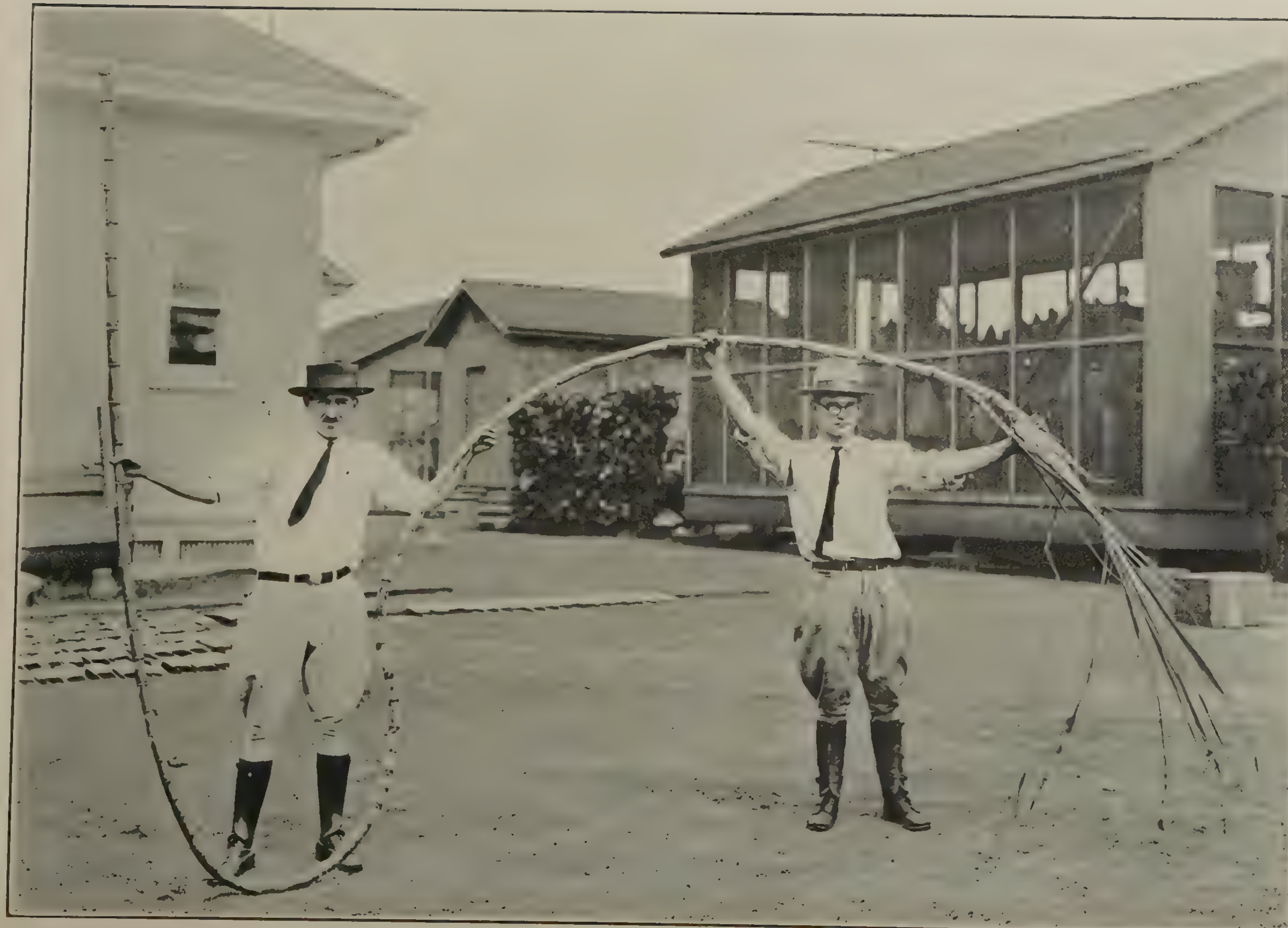

Plate 13. This shows typical stick of sugar cane as grown in the cross-breeding experiments discussed in this article.

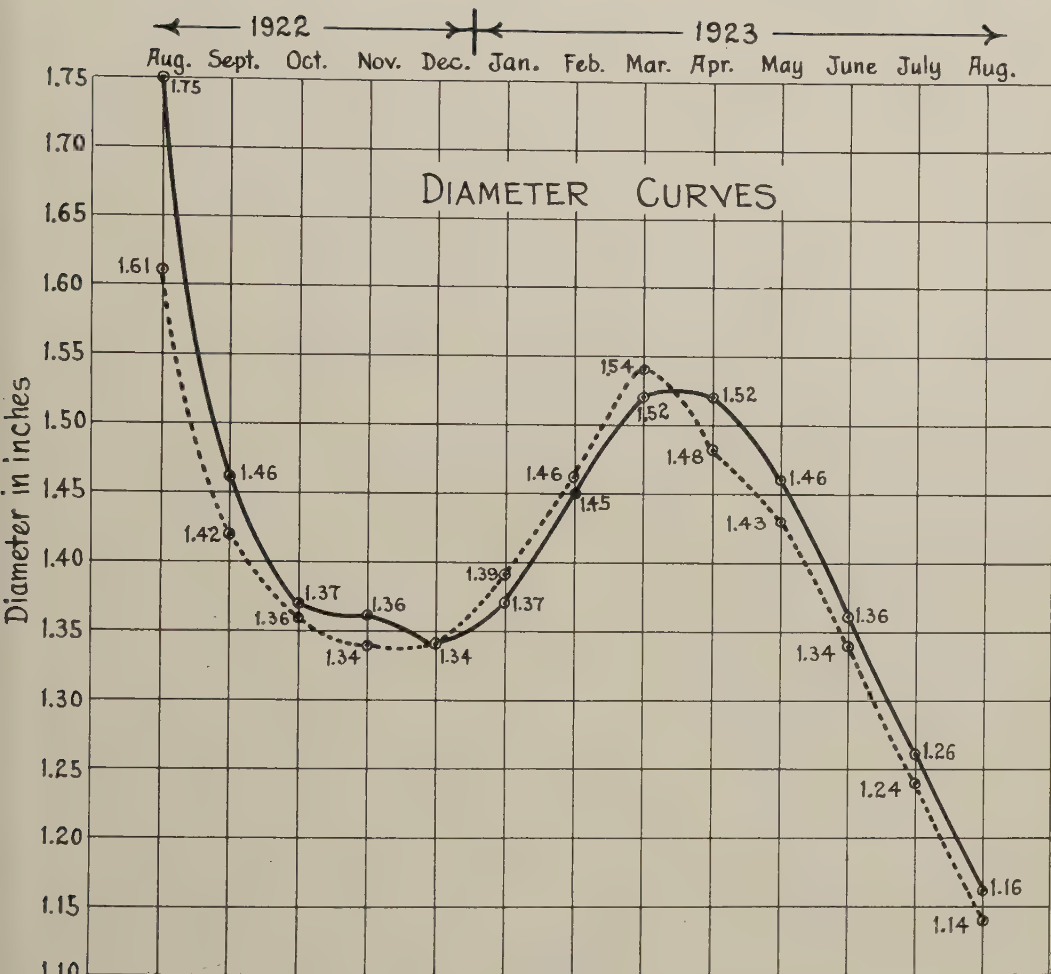

Fig. 7. Average diameter curves for six stalks of H 109 cane, showing differences at an interval of six months. The solid line (————) represents cane 18 months old. Measurements made on each month's growth from August, 1922, to August, 1923. The broken line (— - — —) represents the same cane 24 months old. Measurements made on each month's growth for the same period of time (i. e., August, 1922, to August, 1923). In each case measurements were made at the same places on each stick, using a micrometer caliper.

Rodent Control in Hawaiian Cane Fields*

By C. E. Pemberton.

Among the numerous factors operating in destruction of food, the rat and the mouse play a conspicuous part the world over. These time-honored pests have been trapped, drowned, clubbed, burned and generally mistreated by humanity for ages, and have responded since the dawn of history to the present day by taking an annual toll in food products amounting to many millions of dollars in every civilized country and by spreading diseases fatal to man, at a rate all out of proportion to the abuse received at his hands. We have declared no truce with our ancient and innumerable foe. The war goes on. It were but an idle boast to say that victory is in sight or great progress made during the past twenty years in rodent warfare, when we learn that some ten million men, women and children died in India alone from rat plague since the last great pandemic started in Canton, China, in 1894. This average annual mortality of nearly 500,000 souls for India, not to mention a heavy fatality among most of the other races of mankind, and even here in Hawaii, where it still persists, is ample proof that enlightened man with all of his marvelous advance in every branch of science, at present still lives in close daily association with a pest which continues to increase and which, we believe, has a population even greater today than ever before.

This great prosperity in the rodent ranks would seem to depend solely upon the growth of human population and the coincident increase in the production and storage of food. Admittedly, rats and mice, in general, exhibit a total indifference to our obviously puny efforts towards their extermination or even control. Can we, the investigators, the biologists, the scientists, who are entrusted to captain the battle, feel optimistic with the present outlook? Can we confidently inform our fellow-men that rodents have been placed under any control whatsoever, by our efforts, when we know from the most authoritative estimates that the United States suffers an annual loss, from their depredations, amounting to from thirty-five to fifty million dollars, Great Britain an equal amount, Germany forty-seven and a half millions, France thirty-eight and a half millions, and little Denmark three millions? What can we answer to such an estimate as that made by David E. Lantz, of the U. S. Bureau of Biological Survey, when he found on careful consideration that the city of Baltimore loses foodstuffs yearly, through rodent activities, amounting to $700,000.00 in value, and Washington, D. C., $400,000.00? Have we prospered in our warfare? Rats and mice would seem to have found their Utopia.

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* Presented at the Sugar Section of the first Pan-Pacific Food Conservation Conference, Honolulu, July 28 to August 14, 1924.

Rodent control is by no means the least important of our problems in the Pacific and in the countries adjacent thereto. The reality and seriousness of their depredations fully justify us in placing them among the important subjects included in this conference.

In the Pacific we have, in recent years, some striking examples of what rats and mice may do when food, housing and climate favor them. During the late World War losses in Australia at large grain-storage centers, became a great burden to the producers. The invasion of rats a few years ago on Lord Howe

Damage to cane by rats can be greatly reduced by systematic methods of poisoning, as described in this article.

Island, off the coast of New South Wales, promises to be a classic in the history of the advance of this rodent. The very existence of its few inhabitants has become threatened. Producers of copra in some of the Pacific Islands suffer heavy losses and where sugar cane is grown the problem often becomes particularly acute. In Java, India, Australia, the Philippines, the Mariana Group and in Hawaii we have heard much of the destruction to growing cane by rats.

Because of these losses in Hawaii on certain of the sugar plantations, a determined and well organized campaign in rodent control has recently been launched, which, because of the extent of the operations and the results which so far seem to have been obtained, make it of particular interest and perhaps worth special mention at this conference. With the ever increasing efficiency in the production of sugar in Hawaii and the gradual elimination of many of the problems that have appeared, planters in these islands have grown to feel, perhaps more so than in most other agricultural regions, that any problem in their business is highly susceptible of solution. A history of their achievements would tend to indicate this as a natural sequence. Hence the rat problem, which had been shelved as of secondary importance for many years, finally received attention and on one plantation on the island of Hawaii a bold and carefully laid plan of warfare was plunged into and a system of operation developed, which, we judge, even in one year's time, brought consternation in the array of the enemy. Because of these results and the interest thus aroused, it is the purpose of this paper to briefly summarize the extent of the problem, the procedure at Honokaa where the work has been done and outline how far success has been attained, so far as we can judge, and wherein there is yet failure.

The sugar industry is affected by rats, not so much in the final product as in the field. Rats are particularly fond of the sweet stick, securing therefrom the greater part of their carbohydrate requirement. Large holes are eaten into it or sometimes the stick is eaten clear through. Wherever even a single joint is so injured, souring, fermentation and rot follows up and down through the live tissue causing an appreciable deterioration in the purity of the juice in almost the entire stick and hence there follows a reduction in the quantity of sugar finally manufactured therefrom. Rats become so numerous on some of the plantations that the percentage of sticks so injured is large. At Honokaa plantation, where the extensive methods of rat control have been developed, estimates of the quantity of canes rat injured range from about 15 per cent to 25 per cent. Careful analyses of injured sticks have shown that those bearing an average injury lose from 10 per cent to 14 per cent of their sugar. From these data it is most surprising to know that at this one plantation alone the computation shows an annual loss conservatively estimated at from $60,000.00 to $75,000.00. To more fully appreciate the importance of the problem one need but examine the records of trapping operations at this one place. From 1914 to 1922 inclusive, several hundred steel traps, daily set in the cane and camps, caught the huge total of 347,762 rats. This shows the enormity of the rodent population, sustained in great part by live sugar cane. Such trapping, however, merely scratches the front line of the horde, for on the 14,000 acres of land covered, a few hundred traps can make a very small impression.

By 1922 it was realized that to combat such prolific and voracious animals required more heroic methods than the use of traps. Early that year poisoning was seriously considered. Without elaborating on the preparation and experiment preliminary to the adoption of a final system, it is sufficient to state that consideration was given to many forms of poison, which included poison gas, bacterial viruses, cyanide, arsenic, phosphorus, extract of squills, barium car-

bonate and strychnine. The latter two have given promise of being the best of the lot. Early experiments with both indicated that the best chances for control would probably be obtained through the adoption of a system of poisoning with these substances in exclusion of everything else. These two poisons were made up in baits and used extensively in 1922 and 1923 and are still being applied persistently this year. An examination of the cane in each field that was harvested in 1922, which had not received poison, showed rat damage in 18.9 per cent of the sticks. The poisoning in 1922 was in cane to be cut in 1923. When this 1923 crop was cut a similar careful percentage count was made in every field during the entire period of harvest. This showed an average rat damage of 4.29 per cent with a coincident disappearance of rats. Here was a great reduction in damage as compared with former years. We are faced also with the pleasant fact that though twelve deaths from bubonic plague occurred in the district in 1922, there was only one in 1923 and so far none in 1924.

Until proven otherwise we must assume that this cessation of heavy rat damage to the cane and the great reduction in the quantity of rats about the plantation, is due to the poisoning. The absence of human plague may be due to other causes, for it has not been confined solely to Honokaa, though of recent years Honokaa has been at the center of the human plague infection.

Of the two poisons used, barium carbonate has been the most widely distributed. It has been used in cake form, is cheap, highly toxic to rats, does not deteriorate, is almost tasteless and odorless and available in any desired quantity for such work as rodent destruction. The cakes are composed of wheat flour and middlings, with the white powdery barium carbonate mixed in at a proportion of three parts flour and middlings to one part barium carbonate. This is moistened, kneaded, rolled into one-fourth inch sheets and circular one-half inch cakes cut from it. These cakes are then dried and given a thin coating of paraffin for better preservation. They are distributed about three times a year in amounts of approximately one cake per 100 sq. ft. of land. No gulch, rock pile, camp or waste area is missed. As the area treated is about 14,000 acres, it can be well understood that the campaign is one of no small dimension. The selection and supervision of the labor in the application is an item in the work, of importance, since thoroughness of poison distribution has been proven highly essential. It has been found desirable also to test every barrel of poison before mixing it into baits. This is done with live rats kept for the purpose. Over 350 separate tests have been concluded. They further serve to confirm the original contention both here and in other countries that barium carbonate, as well as strychnine, is strongly toxic to rats. Wheat, coated with crystals of strychnine (alkaloid) at the rate of one ounce strychnine to 25 lbs. of grain, has also been extensively used, the wheat being applied in paper torpedo form, using about one-third ounce of wheat per torpedo package. This is a satisfactory poison, as is being demonstrated by some of the other plantations in Hawaii and in other parts of the world.

Except in large cane, the distribution of the two types of poison just described, can be broadcast from horseback at low expense. The manufacture and appli-

cation of these poison baits at Honokaa has cost about $5,000.00 a year. Judged from the results to date the cost is negligible.

The problem has not been one of finding a poison that will kill rats. Many poisons have long been known to be fatal to them when they eat it. Barium carbonate and strychnine have been recommended and used in many parts of the world for years. The problem has been here, as elsewhere, one of inducing rats to eat substances which will kill them. This involves the mixing and masking of materials in form attractive and suitable to their taste and then placing it out in such quantity and frequency that the rate of mortality exceeds the birth rate. It sounds simple enough but were this true we would have no rat problem today. Of necessity, when dealing with such a host of rats, strict economy is required in the choice of materials used in the bait. Expensive and palatable substances such as cheese, bacon, fruits, etc., might be used by the wrathful housewife in laying a bait to gain revenge on a wily rat, but the farmer with thousands of acres to protect, has no recourse to such luxuries. Hence deeply involved in the problem are the two questions of palatability and economy. The hard, dried, wheat-cake above described containing the almost odorless and tasteless barium carbonate comes nearer to answering the requirements than any other bait yet developed at Honokaa. It is far from perfect. It is not particularly attractive, nor does flavoring seem to improve it. Still it is practical and enough rats seem to take it to accomplish, in part, the end striven for. The same can be said of strychnine-wheat though its cost is considerably greater than that of the barium carbonate cake.

Much has been said and written of the cunning nature, keen instinct and intelligence of the rat. Two years of constant study and field experience with the rat at Honokaa would at least fully confirm the assertions respecting a remarkable endowment of senses in hearing, tasting and smelling. All the difference between success and failure in rat control can result from the slight moulding of the baits before application. It has been just lately determined that a very great difference in the percentage of poison cakes eaten will occur if the barium carbonate is mixed all through the cake or only compacted as a central core. In the former, much fewer cakes are consumed than in the latter. This indicates how readily a rat may recognize the presence of poison at the first nibble though the material be to us absolutely odorless and tasteless. The slight alteration in the distribution of the poison in the cake by fixing it in the pure state, but sweetened, in the center, but not on the surface, has enabled us to score a point on the rat by inducing it to gnaw into the pure poison. This is because of the edibility of the unpoisoned coating. This new form of bait is proving more fatal in the field and laboratory than the old. Mixtures may thus prove less effective than baits resembling sandwiches or encrusted pills. It must first pass the tests of months of time and experience.

In connection with any comprehensive investigation of rats, a thorough test of a plan of extermination involving sex control should be included sooner or later. This theory, championed notably by William Rodier, of Australia, and apparently successfully applied by him against rabbits, is based on the belief that any tilting of the balance of sex ratio, in favor of the females, heavily

assists the rat in the fulfillment of its polygamous instincts and thereby increases the number of offspring in the life of each female. In other words, by destroying males more rapidly than females the birth rate proportionately increases, and vice versa, the reduction of females and protection of males tends toward extermination through the activities of the latter. We believe the theory to be sound, but impractical in application to rats owing to the insurmountable difficulties implicated in the capture and liberation of males and destruction of females in quantity sufficient to materially reduce a rodent population of millions, rather than thousands, whose increase from a single pair in one year may reach 800 in number where food is sufficient and climate salubrious. In correlation with this theory we are told that man's perpetual warfare on rats, by its very method, has favored their increase, since trapping, poisoning, etc., destroy more males than females, owing to the greater boldness and activity of the former. Certainly all sex determinations the world over on trapped rats have shown a preponderance of females, the conclusion from this being that our warfare has kept the males reduced. We feel, however, that in poison control the theory hardly applies. We cannot unreservedly conclude that males must necessarily eat much more than females or in feeding show less acuteness in the avoidance of poisons. We can hardly conclude that the so-called Rodier theory yet applies at Honokaa, for the poisoning has surely checked rather than increased the rodent population.

Any control of rats by poisoning must be continuous. There can be no let up. Their potentialities for increase are enormous and any reduction only enables those remaining the better to mature and reproduce. A day or week annually set aside for rat destruction, though it be conducted on a wholesale scale can be of little avail. Until we recognize the problem as one requiring continuous attention, on a broad scale, classed with all other important items in food production such as irrigation, fertilization or cultivation, progress will be but short-lived. An acceptance of the question in this light has been largely responsible for the partial success already attained at Honokaa. The neglect of a single large field of cane, or a slip in the machinery of the adopted system has several times been believd to account for an uprising of rats in that field.

Though the gray, or so-called migratory rat, *Rattus norvegicus,* is the one we have primarily to deal with and is said to be strongly nomadic in habit, we believe these sporadic outbreaks, which still appear in the poisoned region, to be sudden enlargements of more or less permanent colonies within the fields, which escaped thorough poisoning, rather than over-night invasions from the adjacent unpoisoned country.

As indicated above we would not leave the impression that this poison campaign has developed a degree of control in excess of our expectations or led to results that leave little for improvement. There have been several isolated outcroppings. Unexpected and heavy damage has appeared in spots. The chain is weak in places. The results, in general, cannot be said to be better in 1924 than last year and it leaves us yet in some doubt for the future. But we have only to recall the situation prior to the advent of poisoning to realize that there has been a large saving for two consecutive years and that the fields, though today showing damage in places, are in general much improved. It leads us to hope

for bigger results through an enlargement of the system and improvement of the bait.

What are the possibilities for better rodent control in our cities? To one who has struggled with the problem and seen some degree of success on a 14,000-acre sugar plantation, situated in a rough, steep, irregular country, interspersed with no end of deep gulches overgrown with a tangle of shrubbery, where rock piles and waste areas in further tangle are numerous and where an ideal home for this ground-inhabitnig rat would seem to be reserved, the problem in cities would appear quite small. When, knowing the physical difficulties of distributing poison in well-grown sugar cane, where an almost impassable jungle is entered, where distance and direction are easily lost, and where the chances for poison bait deterioration through rain, irrigation, etc., are great, the problem in cities dwindles to still smaller proportions. In comparison, the situation for conducting a systematic control in all cities would seem ideal. Carefully laid plans could be exactly and timely executed. It is not, however, wholly simple. The variety of food utilized by rats in cane fields cannot be great. In cities, it is, and most baits applied would not be as readily acceptable to a city rat as in the field. However, it is believed that not enough system or perseverance is generally used in poisoning rats and that the conduct of some continuous plan, such as is being carried out at Honokaa, must be the only one whereby constant control can be achieved, both in the city and in the field.

Present Needs in Cane Disease Control*

By H. Atherton Lee

An ounce of prevention is worth a thousand pounds of cure. This is the old Scotch epigram modified to fit the situation in regard to the curing of cane diseases, and it is not at all difficult to find instances to illustrate the truth of this old saying.

Take the case of mosaic disease, nearly all cane men know of the outbreak of this trouble in Porto Rico. There is considerable circumstantial evidence to indicate that mosaic disease has been well established in oriental countries for years and that it is a trouble comparatively new to sugar countries of the Western Hemisphere. Mosaic disease was known in Java as early as 1890 and has existed in the Philippines for years; it was first noticed in Porto Rico in 1916. The disease is known to have spread to Egypt on cane cuttings imported from Java. Cuttings of cane from Java are also known to have been imported into the Argentine, and it is known that cuttings with mosaic disease were introduced into Porto Rico and Cuba from the Argentine.

* A paper presented at the First Pan-Pacific Food Conservation Conference, under the auspices of the Pan-Pacific Union.

If we go back over this trail, therefore, it can be seen where mosaic disease could have been stopped inexpensively and easily. If the cane introduced into the Argentine had been carefully selected in Java, there would have been no mosaic disease in the Argentine. If the cane had been carefully selected in the Argentine before its introduction into Porto Rico, the trouble would have been prevented very economically in Porto Rico. Exclusion of mosaic disease would have saved Porto Rico from enormous expense, an expense which is being repeated year after year and probably will be repeated annually for some time to come. Exclusion of mosaic disease would have saved sugar yields for the Argentine and for Cuba and for Louisiana, also, at practically no cost.

But there are other good illustrations of the way in which an ounce of prevention of cane diseases is worth many pounds of cure. Fiji disease, which is a comparatively new trouble in the Philippine Islands, is another good instance of how precautions to secure exclusion would have saved some of the growers

The effect of Fiji disease. At the left is a stool of the Luzon White variety showing the stunting effect of Fiji disease; at the right is a normal stool of the same variety.

considerable worry and added to their cane yields year after year. Fiji disease has been known in the Fiji Islands, Australia and New Guinea since the year 1910. In 1916, it was found in the Philippines and there is circumstantial evidence to indicate that it was introduced there on cane cuttings imported from Australia about the year 1912.

There are many other examples: Downy mildew of sugar cane is a disease carelessly imported into Formosa and later from Formosa into the Philippine Islands. A new trouble, known as red stripe, caused by bacteria, is an introduced disease in Hawaii; gum disease, also caused by bacteria, is an introduced

trouble in Porto Rico; wilt, caused by a fungus, is an introduced disease in the Philippines.

There are two extreme views in regard to cane diseases. One class of cane men regards all cane diseases as devastating, calamitous troubles, and the word "disease" to them brings up visions of blighted crops and bankruptcy. Another class looks upon all cane diseases as negligible troubles, similar in nature to leaf spots. There is a middle ground which regards cane diseases as having varying degrees of seriousness. Leaf spots, as a rule, are usually negligible except under extreme conditions favoring their development. On the other hand, there are more serious troubles, such as mosaic disease, Fiji disease, cane smut, downy mildew, and gum disease, which very materially lessen yields. Although entire destruction of a crop is a very rare thing, in some cases one or several of these diseases have been known to cause total failure in one or several fields. Whenever one of these troubles is at all common there is usually such a material reduction in yields as to form the difference between profit and loss, particularly in years of poor prices.

The rows of cane on the left are affected with Fiji disease; they are of the same age as the healthy cane on the right. This disease is not in the Western Hemisphere as yet. The cheapest cure in the Western Hemisphere is an ounce of prevention, that is, entire exclusion.

Probably the worst cane disease in the countries of the Western Hemisphere is mosaic disease. This is only one serious trouble, while in oriental countries there are a number of diseases, any one of them often as serious as mosaic and sometimes more serious.

Fiji disease, for instance, is an infectious trouble, known to be transmitted by cane cuttings but the cause of which is unknown; it is now found in Fiji,

Australia, New Guinea and the Philippines, and has not yet been introduced into cane countries of the Western Hemisphere, nor has it reached Java, India, Mauritius, Natal or Egypt as yet. This disease can be prevented with no cost at the present time in Hawaii, Cuba, Porto Rico, Louisiana, the Argentine, Mauritius, India, Egypt, and Java by entire exclusion. In other words, now is the time to exercise the ounce of prevention for Fiji disease. No canes should be imported into these countries from Australia, the Philippines, or Fiji except after personal inspection by a competent authority on cane, cane diseases and cane insects. Even after such selection the new cane varieties, when imported, should be kept in isolation for the plant crop and one ratoon crop. Distribution of cuttings of the new imported variety should not be made until the first ratoon crop has been harvested. We know of no cane varieties, as yet, with any high degree of resistance to this trouble. H 109, the Cheribon canes, Yellow Caledonia, Uba and all commonly grown varieties are susceptible.

Downy mildew is another trouble, caused by a fungus, and known to be transmitted by cane cuttings; it is found only in Formosa, the Philippines and Australia and has not reached the Western Hemisphere and is still unknown in Java, India, Mauritius, Natal and Egypt. In the Philippines, Uba cane is especially susceptible to downy mildew.

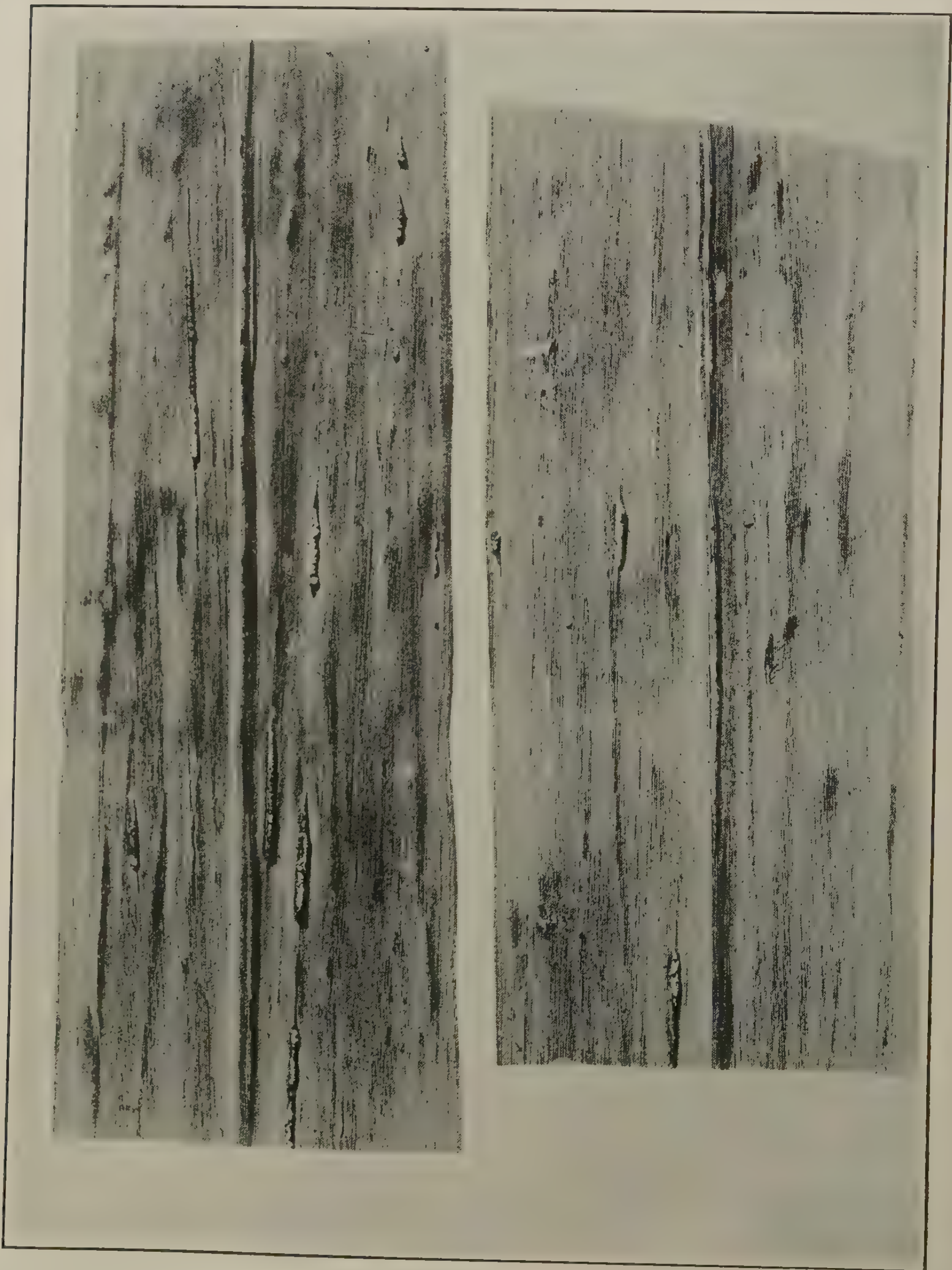
Cane smut, caused by a fungus, is known to be transmitted by cane cuttings. It is reported from India, Natal, Java, Italy, Mauritius, the Philippines and Australia, and two points in the Western Hemisphere, Trinidad and British Guiana. In the Philippines, Uba cane is also especially susceptible to cane smut.

Sereh is a trouble, the cause of which is unknown, but it is well established that it is transmitted by cuttings. It is authentically known only in Java as yet, although there are reports that it is also in Formosa. It is not known as yet in any of the other cane countries. It is probably only good fortune that it has not been introduced into the Argentine, since cuttings were imported there direct from Java.

Gum disease, caused by a bacterial organism, was first known authentically from Brazil and later in the year 1893, from Australia. It is also known in New Guinea, Mauritius, Reunion, and Porto Rico. What is considered a similar trouble is known in Java, Borneo and the Philippines. It is transmitted by cane cuttings. Gum disease is not known as yet in Hawaii, Formosa, India, Egypt, Natal, Louisiana nor Cuba. A new trouble is being reported from Australia, known as leaf scald, caused by a bacterial organism. It is not known from other countries. Red stripe disease is a new bacterial disease in Hawaii which is not known in other countries.

These are the more serious troubles, the most of which have not yet become established in the cane countries of the Western Hemisphere. The absence of these diseases is a considerable advantage to western countries in competition with oriental countries where labor is so much cheaper. This advantage may be maintained by the exclusion of these cane diseases. What is needed in cane countries of the Western Hemisphere is a considerable campaign of publicity concerning these well established and destructive cane diseases in the Orient. Every cane man should know of the existence of these diseases in other coun-

tries, and having such knowledge, should insist that no cane importations be made except by competent cane men working in close contact with men versed in cane diseases and cane insects. It is a sad fact to contemplate, but in the illustrations of the importations of cane diseases which have just been related, in



Small longitudinal galls appear on both surfaces of the leaves of cane affected with Fiji disease. Such galls constitute a reliable feature for identification of the disease.

four instances, government experiment stations and rather well-known cane men are implicated as having brought about the introduction and distribution of these diseases; inadvertently and innocently, it is true, but nevertheless the harm has been done.

To summarize: an ounce of prevention against cane diseases is worth many pounds of cure. Now is the time for cane sugar producers in the countries of the Western Hemisphere to exercise the ounce of prevention against Fiji disease, downy mildew, sereh, cane smut, wilt, gum disease, leaf scald and possibly other unknown troubles and numerous insect pests.

If new cane importations are to be made, and progress in cane production necessitates such importations, selection of the cane cuttings to be imported should be made by a competent authority. The imported cuttings should be grown in isolation under government supervision for at least one plant crop and one ratoon crop. During this period of quarantine, inspection should be made several times each month by cane men working in close co-operation with cane entomologists and cane pathologists.

The Athel in California

By A. D. Shamel

In the spring of 1922, Mr. Bloomfield Brown, of the Hawaiian Pineapple Company, at Wahiawa, asked the question as to whether or not we knew of any rapid-growing tree other than the eucalyptus suitable for windbreaks. I suggested that the athel, or tamarisk, might be worth trying. It has been recently introduced in the Southwest and its rapid growth under desert conditions has been very striking. At Mr. Brown's request, I brought to Hawaii some cuttings of Athel, part of which were given to Mr. Brown and the remainder to the Experiment Station of the H. S. P. A.

Since this introduction, I have had the opportunity of studying rather extensive athel windbreaks in the Coachella and Imperial Valleys of California, on the Yuma Mesa and in the Salt River Valley of Arizona. These observations showed that the athel trees have made satisfactory growth in nearly every instance and that the hedges of these trees are satisfactory windbreaks. However, contrary to previous impressions, it has been found that these trees, under the conditions studied, are as competitive, if not more competitive, with neighboring plants than are the Eucalypti (*E. rudis, E. globulus, E. viminalis*) under the same conditions.

For example, near Brawley in the Imperial Valley, a grapefruit grower, Mr. Steiner, showed us roots of athel trees of a five- or six-year-old windbreak alongside his grapefruit orchard, extending 45 feet into the grapefruit orchard soil. On the Yuma Mesa, a windbreak of athel trees on the Hill Citrus Orchard property showed similar results of severe competitive conditions of growth

on the part of the athel trees. It may be that, under some conditions, the root growth of the athel trees will not be so competitive with neighboring plants as observed last summer in our study of this subject. However, it seems advisable, from our point of view, to proceed cautiously in Hawaii until the habit of growth of this tree is actually determined from experience.

I feel that it is desirable to try this desert tree in the dry districts of Hawaii both for windbreak and ornamental purposes, but only on a small scale until its habits of growth are determined in each district and under different soil and climatic conditions.

The Athel in Hawaii

By H. L. Lyon

The athel, or evergreen tamarisk, *Tamarix aphylla,* gives promise of becoming a valuable tree in Hawaii, but its range of usefulness and its adaptability to our varying conditions of soil and climate, have yet to be determined.

This tree was introduced into the United States from the arid regions of Northern Africa and has been strongly recommended for planting in the deserts of Arizona and southern California. It has been frequently stated that it did not produce surface roots and consequently would not interfere with the growth of neighboring plants. According to A. D. Shamel, who brought the first Athel cuttings to Hawaii, this has been proven an erroneous conclusion. In the short note which precedes this article, Mr. Shamel tells us that under certain conditions in California, the Athel is proving "as competitive, if not more competitive, with neighboring plants than are the Eucalypti." This is a matter which should be taken into consideration whenever extensive plantings of this tree are contemplated.

The numerous tamarisk cuttings which we have distributed in recent months were all imported from California, but we are now able to supply a limited number from our own trees growing at the nursery in Honolulu.

Our first experience with this tamarisk was not encouraging, but since we have discovered the treatment which it requires, we are obtaining much better results. Cuttings planted at the Vineyard Street Nursery during May, 1923, had produced trees which measured 11 feet tall on the first of April, 1924, and 16 feet tall on the first of August, 1924. Cuttings planted in an exposed situation above Wahiawa, at about 1,000 feet elevation, have produced thrifty shoots which are, however, rather slow-growing. We find that the cuttings should be placed in the ground where the trees are desired, for very few of our bedded cuttings have survived transplanting. They should always be planted where they will get full sunlight, for the trees seem to object to even partial shade. They may be started in pots or cans and then transplanted to the ground, but this must be done without disturbing the soil about their roots and we would not recommend this procedure where open ground planting is possible.

The method of handling which we would now recommend is somewhat as follows: Dig holes 12 inches by 12 inches by 18 inches deep, 3 to 5 feet apart. Plant one cutting, slightly inclined, in each hole, the top of the cutting to be about level with the original surface of the soil, and the hole to be filled within 3 inches of the top. This will, of course, leave about 3 inches of the cutting exposed. Keep the soil moderately moist by irrigating when necessary, but do not keep it in a soggy condition. When the young shoots attain a height of 12 to 18 inches, fill in the holes to cover the lower ends of the shoots so that they may develop roots independent of the old cuttings. Large shoots not anchored by their own roots are apt to be split off from the cuttings by the wind.

In general appearance, the athel suggests a *Casuarina* or ironwood. It is a very graceful tree with grey-green foliage and ranks high as an ornamental, being especially attractive when in flower. As it thrives best in hot, sunny situations, we should not expect it to flourish in very wet regions or at high elevations.

These trees were eleven feet tall when eleven months old.

Some idea of the character of this tree may be obtained from the following quotations from literature:

This interesting and beautiful native of the Sahara, contributed to American horticulture by Dr. Trabut, is proving to be an ideal plant for windbreaks in the deserts of southeastern California. The absence of surface roots is a valuable feature, as it makes it possible to grow other plants close to the rows of Athel.

Eighteen months after the cuttings were planted, the trees had reached a height of 20 feet and when 5 years old, some of them were 50 feet high and from 14 to 19 inches in diameter at the base of the trunk.

Rapid growth is by no means the only merit of this tamarisk, for it is highly ornamental and the wood not only supplies excellent fuel, but is said to be of value for construction purposes.

(Kearney, T. H. The Journal of Heredity, 13:157 and 160, 1922.)

A small to moderate-sized tree with feathery foliage; an erect, tapering trunk, and rough grey bark, attaining a height of 60 feet and a girth of 6 to 7 feet or more.

An important tree in arid regions, the wood being used for agricultural implements, turning, and other purposes, as well as for fuel.

It thrives in arid regions with extremes of temperature, where the thermometer reaches a shade temperature of 120 degrees F. or more in the hot weather, while in the winter it sinks below freezing-point; the rainfall in parts is as low as 3 inches.

It coppices freely, sending out quantities of shoots, and grows readily from cuttings but does not produce root-suckers.

The growth is much faster on low-lying ground subject to inundation than elsewhere.

(Troup, R. S. The Silviculture of Indian Trees, 1-18-20, 1921.)

Does Liming Pay?

By J. A. Verret

For a number of years we have been conducting field experiments to determine the value of liming on the fields of the various sugar plantations. In this article we propose to give a summary of our results to date.

Some confusion exists in the popular mind with reference to the nature of lime and its use. Before proceeding with our summary, it may be well to discuss these points briefly.

When the chemist speaks of "lime" he refers to calcium oxide (quicklime) only, but when we refer to lime in the agricultural sense we include three different materials: burned or quicklime (calcium oxide), hydrated or water-slaked lime (calcium hydrate), and ground limestone or air-slaked lime (calcium carbonate). Gypsum or calcium sulphate is not included in the term "lime" although it contains calcium.

These materials contain various amounts of calcium and for purposes of comparison are referred to quicklime, calcium oxide. That is: 56 pounds of quicklime equals 74 pounds of hydrated or water-slaked lime or 100 pounds of ground limestone. The other way about, 100 pounds of quicklime equals 132

pounds of water-slaked lime or 179 pounds of ground limestone. With these figures in mind, one may figure the relative costs. When either quicklime or hydrated lime is exposed to the air, they gradually absorb carbon dioxide and tend to change to lime carbonate, or limestone.

The function of lime in soils is given briefly as follows:

1. Lime materials serve as a source of the element calcium to plants. Calcium is one of the essential elements in plant growth. As a rule most of our soils are pretty well supplied with calcium; besides this, we apply fairly large amounts of it in the phosphates which we use in our mixed fertilizer and directly.

2. Lime materials have the power of shrinking clay and making it more pervious to water and air. Lime, therefore, makes clays and adobe soils looser, and improves the mechanical condition of this type of soils.

3. Lime materials (when used in proper amounts) make "sour" soils "sweet," changing an acid condition into a neutral or slightly alkaline one. This is essential to many crops, but our tests indicate that sugar cane is very tolerant to sour conditions although our best yields are obtained from neutral or slightly alkaline soils.

4. Lime materials are necessary for the beneficial bacteria and other micro-organisms of the soil.

5. Lime materials promote the normal decay of organic matter in the soil.

6. Lime materials, under some conditions, make soluble some of the insoluble forms of the more valuable plant foods such as potash and the phosphates.

7. Lime materials, when added to nearly or complete neutrality, precipitate soluble alumina.

For the purpose of loosening heavy soils mentioned in (2) burned or hydrated lime is to be preferred when prices allow. It acts more quickly. Lime is best applied before plowing, several months before planting, particularly if quick or hydrated lime is used. On the sour, lighter, sandy or loam soils, ground limestone is to be preferred to either of the other two.

KAIWIKI SUGAR COMPANY, EXPERIMENT 1, 1917 CROP, LONG RATOONS

Lime applied before ratooning

Treatment	No. of Plats	Tons per Acre Cane	Q. R.	Sugar
No lime	3	40.9	7.21	5.67
2 Tons coral sand...........	2	44.1	7.50	5.88
4 Tons coral sand...........	2	42.1	7.46	5.64
1 Ton quick lime............	4	40.0	7.39	5.43
Average all lime plots.....		42.1		5.65

WAIPIO SUBSTATION, EXPERIMENT "O," 1918 CROP, FIRST RATOONS, LONG

Lime applied in furrows and mixed with soil

Treatment	Tons per Acre Cane	Q. R.	Sugar
2 Tons coral sand	86.7	8.63	11.51
No sand	87.7	7.37	11.97
1 Ton lime per acre	82.9	6.94	11.97
No lime	84.7	7.37	11.32
6 Tons coral sand	82.8	7.27	11.40
No sand	80.1	7.37	10.96
12 Tons coral sand	69.1	7.15	9.71
No sand	67.7	7.37	9.15
Average all lime plots	80.4		11.15
Average all no lime plots	80.1		10.85

WAIPIO SUBSTATION, EXPERIMENT "O," 1918 CROP, FIRST RATOONS, LONG

Coral, Sand, and Lime, Residual Effect

Treatment	Tons per Acre Cane	Sugar
2 Tons coral sand	95.7	10.44
No sand	93.9	10.72
1 Ton lime	93.0	9.91
No lime	90.9	9 93
6 Tons sand	83.9	9.28
No sand	83.6	9.01
12 Tons sand	79.5	9.84
No sand	68.1	8.48
Average all lime plots	88.0	9.87
Average all no lime plots	84.1	9.29

WAIPIO SUBSTATION, EXPERRIMENT "O," 1920 CROP, THIRD RATOONS

Testing residual effect of lime

Treatment	Yield per Acre Cane	Q. R.	Sugar
Lime	66.1	8.03	8.37
No lime	64.2	7 82	8.34

WAIPIO SUBSTATION, EXPERIMENT "O," CROPS 1916, 1918, AND 1920

1918 and 1920 crops resdiual effect

	Cane	Sugar
Average of 3 crops—sand	78.3	9.79
Average of 3 crops—no sand	76.1	9.49

WAILUKU SUGAR COMPANY, EXPERIMENT 1, 1917 CROP

Sand applied after furrowing and before preparing, plant cane

Treatment	No. of Plots	Yield per Acre Cane	Sugar
10 Tons coral sand	36	86.4	12.40
No sand	36	81.2	12.18

WAILUKU SUGAR COMPANY, EXPERIMENT 1, 1919 CROP, FIRST RATOON

Residual effect of coral sand

Treatment	No. of Plots	Yield per Acre Cane	Yield per Acre Sugar
Sand	36	74.1	10.87
No sand	36	71.2	10.68

KILAUEA SUGAR PLANTATION COMPANY, EXPERIMENT 4, 1917 CROP

Treatment	No. of Plots	Yield per Acre Cane	Yield per Acre Sugar
Sand	32	27.2	3.09
No sand	32	25.5	2.94

KILAUEA SUGAR PLANTATION COMPANY, EXPERIMENT 7, 1918 CROP

To test value of coral sand and reverted phosphate

Treatment	Yield per Acre Cane	Yield per Acre Q. R.	Yield per Acre Sugar
Nothing	31.5	8.54	3.69
Sand	31.9	8.55	3.73
Reverted Phosphate	31.9	8 58	3.71

HAMAKUA MILL COMPANY, EXPERIMENT 1, 1918 AND 1920 CROPS

Comparing no lime with coral sand and ground limestone

Treatment	Yield per Acre			
	1918 Crop		1920 Crop	
	Cane	Sugar	Cane	Sugar
2 Tons sand	14.7	1.88	26.4	3.44
No sand	15.4	1.99	25.4	3.37
4 Tons sand	15.2	1.90	27.1	3.60
No sand	14.5	1.87	26.6	3.53
2 Tons ground rock	16.3	2.03	27.5	3.71
No rock	15.6	2.01	28.4	3.77
4 Tons ground rock	15.0	1.90	25.7	3.39
No rock	15.1	1.96	24.4	3.28
Average all lime plots	15.3	1.93	26.7	3.53
Average all no lime plots	15.2	1.93	26.5	3.52

HAMAKUA MILL COMPANY, EXPERIMENT 2, 1918 AND 1920 CROPS

Comparing no lime with lime and ground limestone in long ratoons

Treatment	No. of Plots	Yield per Acre			
		1918 Crop		1920 Crop	
		Cane	Sugar	Cane	Sugar
1 Ton lime	4	11.2	1.32	20.5	2.75
2 Tons gr. limestone*	4	11.7	1.44	20.1	2.39
3½ Tons lime	4	10.7	1.25	20.9	2.68
7 Tons gr. limestone	4	11.2	1.35	21.9	2.69
No lime	9	11.0	1.34	19.2	2.43
Avge. all lime plots		11.2	1.34	20.8	2.63

*The higher results in these plots are due entirely to the yield from one plot (3B), which yielded 14.07 tons of cane and 1.72 sugar. No other B plot produced over about 11 tons of cane. The high yield in that plot is evidently not due to liming, but to soil variation.

OAHU SUGAR COMPANY, EXPERIMENT 8, 1918 CROP

Lime and gypsum on virginal land, applied in furrow before planting

Treatment	No. of Plots	Yield per Acre Cane	Q. R.	Sugar
2,000 lbs. lime	12	67.8	9.56	7.25
No lime	12	65.6	9.24	7.18
4,000 lbs. gypsum	10	69.7	9.68	7.35
No gypsum	8	73.6	9.89	7.40

OAHU SUGAR COMPANY, EXPERIMENT 17, 1918 CROP

Coral sand applied to furrows and hoed in

Treatment	No. of Plots	Yield per Acre Cane	Q. R.	Sugar
6 Tons coral sand	9	67.3	11.18	6.03
No sand	9	67.6	11.06	6.11

OAHU SUGAR COMPANY, EXPERIMENT 17, 1920 CROP

Residual effect of coral sand

Treatment	No. of Plots	Yield per Acre Cane	Q. R.	Sugar
6 Tons coral sand	9	96.6	7.05	13.70
No sand	9	101.6	7.43	13.68

GROVE FARM COMPANY, EXPERIMENT 8, 1920 CROP

Sand applied before furrowing

Treatment	No. of Plots	Yield per Acre Cane	Q. R.	Sugar
No sand	9	41.9	8.41	4.98
3¼ Tons sand	9	40.7	8.29	4.91
6½ Tons sand	10	39.5	8.45	4.68
9¾ Tons sand	10	42.0	8.52	4.93
Average all sand plots ...		40.7		4.83

GROVE FARM COMPANY, EXPERIMENT 8, 1922 CROP

Residual effect

Treatment	No. of Plots	Yield per Acre Cane	Q. R.	Sugar
No sand	9	35.50	8.49	4.18
3¼ Tons sand	9	37.5	8.19	4.55
6½ Tons sand	10	33.8	8.61	3.93
9¾ Tons sand	10	33.3	9.49	4.01
Average all sand plots ...		34.8		4.16

HILO SUGAR COMPANY, EXPERIMENT 18, 1921 CROP

Lime applied to 4 ratoons and cultivated in by mules

Treatment	No. of Plots	Yield per Acre Cane	Sugar
No lime	6	49.3	6.16
2,000 lbs. quicklime	6	49.3	6.16
8,000 lbs. coral lime	6	51.0	6.37
Nothing	5	41.2	5.15
12,000 lbs. quicklime	4	44.6	5.57
Average all no lime plots............		45.2	5.65
Average all lime plots		47.3	5.91

HILO SUGAR COMPANY, EXPERIMENT 18, 1923 CROP

Testing residual effect

Treatment Lime applied to 1921 crop	Yield per Acre Cane	 Sugar
1 Ton quicklime	64.1	7.12
4 Tons coral sand	62.4	6.93
No lime	60.3	6.90
6 Tons quicklime	54.6	6.07
No quicklime	53.2	5.91
Average all lime plots	58.9	6.65
Average all no lime plots	56.8	6.31

(N. B. Sugar estimated at 9 quality ratio)

KAIWIKI SUGAR COMPANY, EXPERIMENT 4, 1922 CROP

Value of lime in acid soil

Treatment	No. of Plots	Yield per Acre Cane	 Sugar
No lime	8	24.6	3.39
6 Tons quicklime	8	24.5	3.21

KAIWIKI SUGAR COMPANY, EXPERIMENT 4, 1924 CROP

Residual effect

Treatment	No. of Plots	Yield per Acre Cane	 Sugar*
No lime	8	34.6	4.33
6 Tons quicklime	8	36.2	4.60

*Sugar estimated at 8 quality ratio

PEPEEKEO SUGAR COMPANY, EXPERIMENT 5, 1922 CROP

Value of lime in acid soil

Treatment	No. of Plots	Yield per Acre Cane	 Q. R.	 Sugar
No lime	8	51.7	7.94	6.52
2 Tons Waianae lime	7	49.4	7.74	6.39
4 Tons Waianae lime	7	50.1	7.70	6.51
Average all lime plots		49.7		6.45

HAWI MILL AND PLANTATION COMPANY, EXPERIMENT 2, 1919 CROP

Value of lime in acid soil

Treatment	No. of Plots	Yield per Acre Cane	 Q. R.	 Sugar
No lime	16	52.3	7.93	6.59
1,000 lbs. caustic lime	8	53.2	7.80	6.82
3,000 lbs. caustic lime	8	54.9	7.95	6.90
Average all lime plots		54.0		6.86

PAAUHAU SUGAR PLANTATION COMPANY, EXPERIMENT 11, 1919 CROP

Treatment	No. of Plots	Yield per Acre Cane	 Q. R.	 Sugar
1 Ton lime	9	43.0	8.08	5.32
5½ Tons lime	9	44.5	8.18	5.45

PAAUHAU SUGAR PLANTATION COMPANY, EXPERIMENT 10, 1919 CROP

Value of lime, plant cane

Treatment	No. of Plots	Cane	Yield per Acre Q. R.	Sugar
No lime	16	45.6	8.20	5.57
1 Ton hydrated lime	8	46.9	8.25	5.69
2 Tons hydrated lime	8	46.4	8.35	5.56
Average all lime plots		46.7		5.62

NIULII MILL AND PLANTATION COMPANY, EXPERIMENT 1, 1922 CROP

Value of lime in acid soils

Treatment	No. of Plots	Cane	Yield per Acre Q. R.	Sugar
2 Tons Waianae lime	8	16.7	8.43	1.92
No lime	8	15.2	8.65	1.80

For greater ease in reference, experiments listed above are herewith given in more condensed form.

LIME EXPERIMENTS

	Plantation			Crop Year	Lime Cane	Lime Sugar	No Lime Cane	No Lime Sugar
1.	Waipio Substation	0		1916	80.4	11.15	80.1	10.85
2.	" "	0	(Residual)	1918	88.0	9.87	84.1	9.29
3.	" "	0	(Residual)	1920	66.1	8.37	64.2	8.34
4.	Wailuku Sugar Co.	1		1917	86.4	12.40	81.2	12.18
5.	" " "	1	(Residual)	1919	74.1	10.87	71.2	10.68
6.	Kilauea Sugar Plant. Co...	4		1917	27.2	3.09	25.5	2.94
7.	" " " " ..	7		1918	31.9	3.73	31.5	3.69
8.	Oahu Sugar Co.	8		1918	67.8	7.25	65.6	7.18
9.	Hilo Sugar Co.	18		1921	47.3	5.91	45.2	5.65
10.	" " "	18	(Residual)	1923	58.9	6.65	56.8	6.31
11.	Hawi Mill & Plant Co. ...	2		1919	54.0	6.86	52.3	6.59
12.	Paauhau Sugar Plant. Co. ..	10		1919	46.7	5.62	45.6	5.57
13.	Niulii Mill & Plant Co.....	1		1922	16.7	1.92	15.2	5.97
14.	Kaiwiki Sugar Co.	1		1917	42.1	5.65	40.9	5.67
15.	Hamakua Mill Co.	1		1918	15.3	1.93	15.2	1.96
16.	" " "	1	(Residual)	1920	26.7	3.53	26.5	3.52
17.	" " "	2		1918	11.2	1.34	11.0	1.34
18.	" " "	2	(Residual)	1920	20.8	2.63	19.6	2.43
19.	Oahu Sugar Co.	17		1918	67.3	6.03	67.6	6.11
20.	" " "	17	(Residual)	1920	96.6	13.70	101.6	13.68
21.	Grove Farm Co., Ltd.	8		1920	40.7	4.83	41.9	4.98
22.	" " " "	8	(Residual)	1922	34.8	4.16	35.5	4.18
23.	Kaiwiki Sugar Co.	4		1922	24.5	3.21	24.6	3.39
24.	" " "	4	(Residual)	1924	36.2	4.60	34.6	4.33
25.	Pepeekeo Sugar Co.	5		1922	49.7	6.45	51.7	6.52
	Average				48.5	6.07	47.6	5.97
	Average Quality Ratio..........				Lime.... 7.99		No lime.. 7.97	

Since 1916, we have conducted a total of twenty-five lime experiments. These were on all the Islands and covered our various soil types.

In looking over the summary we find that in thirteen of the twenty-five some gains were obtained; in twelve there were no gains from the lime. In practically no case were the gains especially large or significant.

The cane plant would seem to tolerate very wide fluctuations in the lime reaction of a soil. We find very good crops being produced on lands which are almost pure coral; good crops are also produced on soils which are extremely acid, requiring 10 to 12 tons of lime to bring to neutrality. This shows that with us the lime problem is not an especially vital one.

The conditions under which liming would be most likely to give the best returns are on the acid mauka soils which respond to phosphoric acid. Liming such soils would improve conditions for the phosphates and likely tend to an economy in their use.

The average quality ratio of the juices from lime plots was 7.99, while that from the no lime plots was 7.97. We thus see that lime hád no effect whatever on the quality of the juices.

Per Capita Sugar Consumption*

Question. What is the average consumption of sugar per person in the United States and how does it compare with that of other countries?

Answer. The average amount of sugar eaten is 2 pounds per person per week, according to the U. S. Department of Agriculture. This includes the sugar used in candies, sweet drinks, and other foods not prepared in the home. The amount of sugar consumed is now higher in the United States than in most other parts of the world, the per capita consumption having increased during the last 100 years from 10 pounds to over 100 pounds.

Country	1913-14 Pounds	1921-22 Pounds
North America—		
United States	89	99
South America—		
Brazil	..	20
Argentine	..	..
Europe—		
Great Britain	93	70
France	44	35
Germany	45	54
Italy	12	12
Spain	14	17
Russia	25	5
Asia—		
British India	22	20
Japan and Formosa	..	15
China	..	5

[H. P. A.]

* From The Official Record, U. S. D. A., Vol. III, No. 30.

Seedling Production at Honokaa

A portion of the 20,000 seedlings germinating at Honokaa Sugar Company and Pacific Sugar Mill nursery, Kukuihaele, Hawaii.

Some Factors in Low-Grade Purging Efficiency

By Walter E. Smith.

The work of W. R. McAllep at this Experiment Station has shown that sucrose can be crystallized from commercial waste molasses by concentration under conditions similar to those existing in regular massecuite, producing a new mother liquor of lower gravity purity than is ever attained in factory practice. This work shows, therefore, that actual crystallization of sucrose is not the limiting factor in reducing molasses purity to a minimum, but shows rather that the mechanical separation of the crystals from the molasses is essentially the vital factor.

It is a recognized fact that purging of a given low-grade massecuite increases in difficulty with increase in density. When such other contributing factors as grain, temperature, conditions of supersaturation, and viscosity as affected by boiling methods are brought to proper standards as we now know them, density remains as the principal known factor influencing the drying rate, or the rate at which molasses is discharged from the massecuite contained in the centrifugal basket. The point at which reduction of molasses purity by increase of massecuite density ceases to be commercially profitable, is then the point at which the expense of operation and maintenance of the additional centrifugal equipment exceeds the profit of the increased recovery. Similarly, failure to purge at the highest density consistent with the capacity of the equipment available means loss in recovery through increased molasses purity.

Present practice in Hawaii provides equipment sufficient to give capacity for a drying cycle of 45 to 60 minutes; in most cases the purity of the resulting sugar is from 68 to 75, with a few factories able to raise the purity to 78 to 82. Inquiry into the factors of low-grade purging shows that little, if any, positive data is available as to the actual rate at which the molasses is eliminated from a given centrifugal load of massecuite. The writer has been interested in low-grade purging since it appears that remelt purity is a most important factor in determining the filtrability of commercial sugar, under any given set of factory conditions.

In order to obtain fundamental data on the rate of drying, a number of tests were made by the writer in which the actual rate of molasses elimination was measured. To do this, the molasses was diverted to a tub, by means of a short trough, and weighings made at intervals of 5 minutes over a period of 90 minutes purging. A few minutes was usually required before the molasses actually reached the tub, but it seems entirely fair to regard this latter point as zero, and to offset the time this much, assuming that it takes a few minutes for the flow of molasses to reach the tub, but that it leaves the centrifugal outer shell at the same rate as it is discharged from the basket.

Fig. 1 shows the data obtained from a series of tests at Koloa and Lihue with a 30″ belt-driven centrifugal; in the graph, actual quantity of molasses discharged is plotted against time.

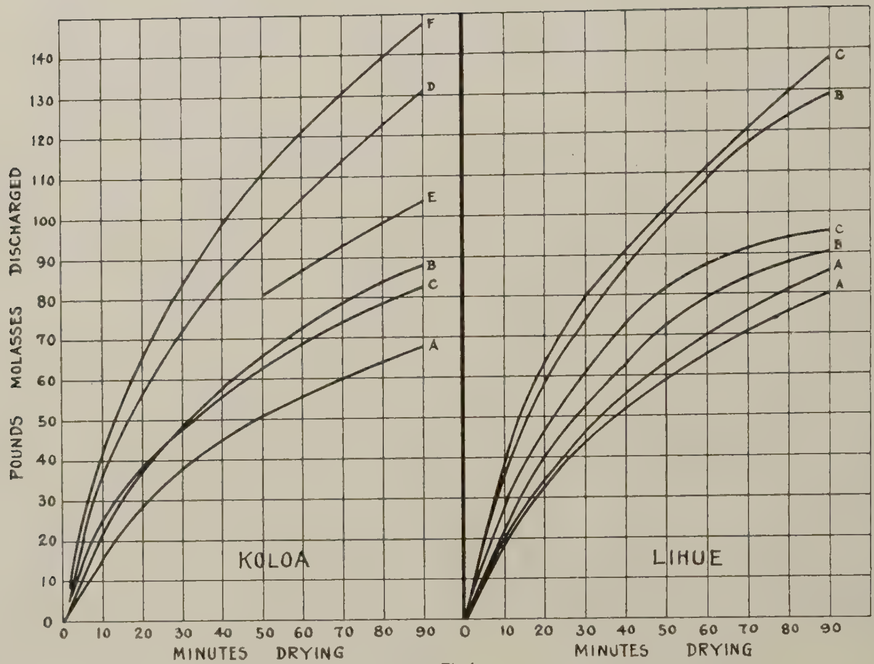


Fig. 1.

In the Lihue series, two tests were made with massecuite from each of three different crystallizers using different quantities in the basket. The following tabulation of data will serve to explain the conditions of the test, as well as the results:

Test	Mass. Brix	Molasses Brix	Quantity of Mass.	No. 2 Sugar Purity	Pounds Molasses 40 mins.	90 mins.	Difference
A-1	96.0	94.8	3.3 cu. ft.	75.2	56	86	
A-2	96.0	94.8	2.0 " "	81.9	53	81	3; 5
B-1	94.8	93.0	3.3 " "	83.4	87	129	
B-2	94.8	93.0	2.2 " "	83.8	63	91	24; 38
C-1	94.2	92.4	3.4 " "	81.3	92	138	
C-2	94.2	92.4	2.0 " "	84.7	73	96	19; 42

The results shown here are very similar to those secured at Koloa, and indicate two general principles:

1. The rate of molasses eliminations tends to increase with reduction of molasses density.

2. At the higher density, with massecuite which would be considered slow-drying, no appreciable loss of efficiency is noted by reducing the quantity of massecuite per load. The difference in molasses elimination due to difference in load tends to increase, however, with the faster-drying massecuites. This condition is also well demonstrated in the Koloa tests, as shown in the following tabulation:

Test	Quantity of Mass.	Pounds Molasses At 40 mins.	Difference	At 90 mins.	Difference	No. 2 Sugar Purity
A-1	2.2 cu. ft.	45	..	68	..	78.0
A-2	2.8 " "	45	0	67	0	73.0
A-3	3.4 " "	46	1	67	0	69.0
C-1	2.4 " "	..	..	83	..	78.0
C-2	3.5 " "	..	..	85	2	69.0
D-1	3.4 " "	85	..	131	..	76.0
D-2	2.6 " "	85	..	116	15	81.0
F-1	3.5 " "	98	..	148	..	74.0
F-2	2.4 " "	..	..	111	37	81.0

These principles would find useful application under a variety of conditions. Suppose, in one case, a factory had ample centrifugal capacity and was able to dry at high density in order to obtain a low molasses. Here the elimination per square foot of screen area would be low, but by reducing the load per machine a higher purity of remelt results without appreciably affecting the centrifugal efficiency. In fact, the rise in remelt purity would probably more than offset the slight loss by reducing the quantity of No. 2 massecuite to be handled, thus increasing the time available for the drying cycle. In another case, suppose a factory has not maintained proper elimination, and to relieve congestion is forced to dilute a crystallizer to low density to speed up drying. Here the greatest molasses elimination will be secured by filling the machines to fullest capacity.

An important condition indicated by the data shown in the drying curves of Fig. 1 is the greater efficiency of the short cycle over the long drying cycle. To compare 30, 45 and 60 minutes on the basis of Test F, Koloa, allowing 5 minutes for discharging, we find the amount of molasses eliminated to be:

Cycle	Drying Period	Pound Molasses Eliminated (In period)	(In 180 minutes)	% Gain over 60 minute cycle
30	25	76	452	30%
45	40	98	392	13%
60	55	116	348	....

In Test A, Koloa, with the slowest drying massecuite, the relative value of the 30, 45 and 60 minute cycle is 127, 113 and 100. In Test B, Lihue, the relation is 130, 114 and 100.

Disregarding for the moment the effect on remelt purity, the short cycle makes possible an increase in centrifugal efficiency which can be used to advantage in drying at heavier density and thus increasing the recovery by lowering the molasses purity. In reducing a one-hour cycle to 45 minutes, if the load is reduced in proportion, the remelt purity will likely remain very much the same, and the elimination per square foot will not be seriously reduced except in the exceptional cases where the massecuite dries particularly well.

It is thus seen that where pan capacity is large, but centrifugal capacity low, the latter may be favored by a reduction of the time cycle, which increases the elimination per square foot of screen area, at the expense of the quantity of low-grade massecuite boiled. On the other hand, where pan capacity is small, but

centrifugal capacity is ample, the pan may be aided by extending the drying time or reducing the centrifugal charge; this will reduce the quantity of low-grade massecuite to be boiled, because of the higher remelt purity, but this assistance will be secured at the expense of the molasses purity, since the elimination per square foot of screen area will be reduced.

In Fig. 2 are shown the graphs of drying tests at several different factories, the rate of elimination being reduced to terms of "pounds per square foot of

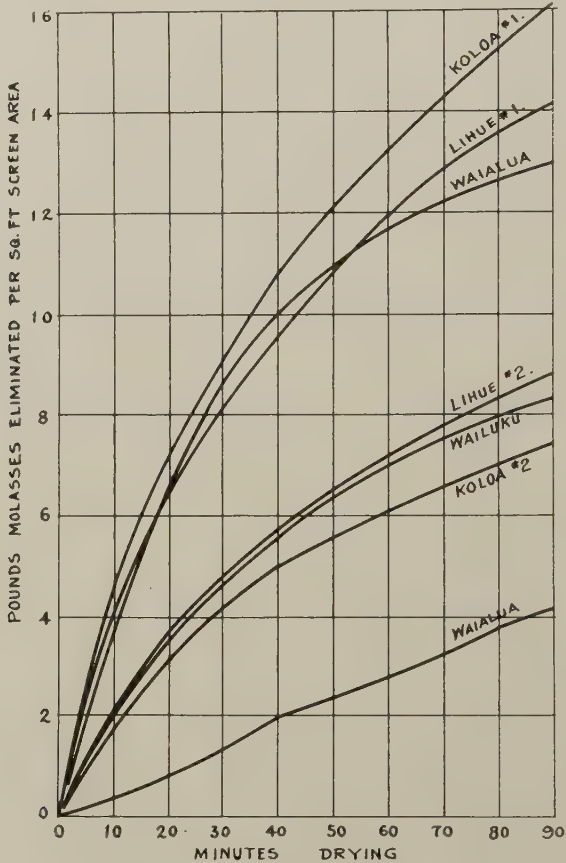


Fig. 2

screen area" to make 30″ and 40″ machines comparable. Before going further, the writer would call attention to the regularity of the curves in the Koloa and Lihue series. In only one test out of fifteen did one curve cross another; in every other case, once the rate had been established by the flow of the first five-minute period, the curve maintained its relative position and direction with respect to the other tests. In Fig. 2, however, the Waialua curve shows a tendency much different from the others. During the first 40 minutes it maintains a high rate; at 40 minutes it is only a few pounds behind Koloa, and actually ahead of Lihue. At 90 minutes, however, the Waialua curve has flattened out and finishes 30 pounds behind the Koloa curve.

A plausible explanation is to attribute this condition to the effect of grain. The Waialua test was made with a massecuite based on syrup grain, and was

actually most irregular. It is entirely to be expected that the influence of grain irregularity should be shown in such a way as this. The massecuite was very fluid, and so attained a high rate of elimination during the first part of the purging; as the smaller grain filled the interstices between the crystals, the flow of molasses was evidently retarded to a marked extent; an almost identical curve was secured at Waimanalo with a massecuite of practically the same characteristics. A similar, though entirely opposite, effect was shown in a Waialua massecuite boiled on "molasses grain" and characterized by marked regularity of grain and an almost total absence of small grain (0.1 mm.). The curve is not included in Fig. 2, as it crosses other curves at two places and confuses the graphs. In this case, during the first part of the curve it lies below Lihue No. 2 and Wailuku, but maintains its original rate so well that it exceeds the Lihue No. 2 curve by 5 pounds at the end.

Summary

Actual measurement of the rate at which molasses is discharged from massecuite indicates:

1. Tendency for rate of elimination to increase with decrease in molasses density.

2. With slow-drying massecuite, load can be reduced without materially reducing quantity of molasses discharged.

3. Approximately 30 per cent more molasses discharged from two 30-minute drying cycles than with one 60-minute cycle.

Comparative Study of the Cane Varieties, Kavangire, Zwinga and Cayanna No. 10*

By P. Richard Kuntz

(Translated from the Spanish by Z. A. Romero.)

Because of the popularity that the Japanese cane, Uba or Kavangire, has obtained, and in view of the many consultations, personal and by letter, for which the planters of this cane are asking, this Experiment Station has decided to publish this small booklet or pamphlet, in which are established the differences and resemblances, from the agriculturist's point of view, between the cane varieties Uba, Zwinga, and Biloxi or Cayanna No. 10.

The industrial part of this subject is fully treated by Mr. Lopez Dominguez, Special Chemist in Charge of Investigations, in his circular entitled: *The Kavangire Cane and Its Yield of Sugar.*

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* Circular No. 73, Insular Exp. Sta. of Porto Rico.

I wish to make clear that the botanical descriptions of the types of cane discussed here are taken from the journal *Sugar Cane Varieties of Porto Rico,* Vol. II, by F. S. Earle.

A period of approximately three years was devoted by Professor F. S. Earle, formerly Expert in Diseases of Cane at this Experiment Station, to the study and observation of mosaic or mottled-leaf disease in Porto Rico. He stated at that time that this disease has been found in all the municipalities of the Islands, except in the Guayanes Valley (Yabucoa). Unfortunately, he now tells us that this disease exists in all sections of the island, including also the small adjacent island of Vieques. The discovery by this same Professor Earle, in the middle of the year 1919, of a variety of cane called Kavangire, completely free from the disease, is a fact of great practical importance. There are now planted in Porto Rico three types or varieties of cane which are completely free of the mosaic; Kavangire (Uba), Zwinga, and the Cayanna No. 10.

It is important that these three varieties be recognized, from the agricultural point of view, as different points affecting their industrial value are constantly coming up; selection should be made in such a manner that the farmer may know what effects may be produced.

Uba or Kavangire

This cane is erect, very vigorous, tillers abundantly and relatively early. The stem or cane is generally thin, with a diameter of 2 cm.; of a clear green color with a lilac cast, and covered with wax. The internodes are large (10 to 12 or 16 to 18 cm.), cylindrical in shape and sometimes reduced at the base. The nodes are of the same diameter as the internodes. The bandings of the rudimentary roots are somewhat oblique and have sometimes measured from 7 to 9 mm., without color, or yellowish in color. The rudimentary roots are well developed, yellow in color, in three rows in somewhat of an agglomerated arrangement. The buds are obtuse-oval, measuring sometimes 10 x 14 mm., in length extending beyond the banding of the rudimentary roots by one-fourth of its width. The leaves are numerous and abundant, somewhat narrow, 3 cm. in width, with an irregular edge, dentate at the union with the sheath.

The immunity to mosaic disease of this variety of cane has been well established not only by experimental work done here, but also by information from the Argentine and some southern states of the United States. Credit for the introduction of this cane is due D. W. May, Federal Director of the Experiment Station at Mayaguez, who brought it in from the Argentine in 1917. By its resemblance to the Japanese forage cane, called Zwinga, it was supposed at the beginning that it also was of Japanese origin and came to be generally known as Japanese. Nevertheless, it seems, according to information published by the Experiment Station at Tucuman, in the Argentine, that this variety is a cultivated one in Japan. It was imported from India to Brazil many years ago; from Brazil it was brought to the Argentine and from there to this island. The authorities on this subject in the Argentine considered it similar to the so-called Uba cane, which is extensively cultivated in Natal, South Africa, and though this perhaps has not been really confirmed they at least are very similar and have

the same history. This cane ratoons very vigorously and for many years, being also very resistant to root disease and completely free of mosaic. It is a hard cane, very fibrous and consequently is not attacked by the stem borer, but is moderately poor in sugar. This cane matures late and should be cultivated well.

From experiments completed, we have reached the conclusion that the problem to solve is the hastening of the maturity of this cane. I would venture to suggest that experimentation be undertaken to control the maturing by means of applying fertilizer containing more phosphoric acid and potash than nitrogen. And if, in addition, we can control the application of water in the three or four months before maturity, who knows if we should not obtain better results in sugar?

The economic points in regard to this cane are its complete immunity to mosaic, its resistance to the root disease and its immunity to gum disease. It is a cane of high tonnage, and in some cases produces more than ninety tons per acre. Another important point that the Uba has in its favor, is that it grows and gives results in soils in which other varieties do not grow at all well. For example, it might be cited that the majority of the plantations in Anazeo and Aguada, planted to this variety, produced, we are informed, approximately about thirty tons per acre. Its thinness make it cost more for cutting and cartage, but this is offset by its ease of cultivation besides its being adapted to a great variety of soils. With reference to cutting and cartage, I take the liberty of translating the following paragraphs from a report on *The Future of the Uba Cane in Porto Rico,* dated June, 1922. It reads:

> Among the many objections given to the Uba cane are the high cost of cutting and transportation by railway. I am of the opinion that the cutting should be done after the burning. It has been demonstrated during the last harvest that by this method said cane can be loaded on cars of the A. R. R. at a cost of 75 centavos to $1.00 per ton, depending on the prices prevailing for the last crop, without profit for the contractors. With respect to the dead weight of said cane (of great volume and little weight) I have found that, by loading with great care, up to 13 tons of cane can be loaded in a car. If we pay $1.50 per dead weight, this should be less by 12 centavos per ton for the 13 tons loaded in the car, and I think that the Public Service Commission would take this into consideration and change to 1 to 12 tons as a minimum load per car. Finally, I wish to make clear that I am convinced that the Uba cane can be brought to the factory at a cost of $3.00 per ton and the production of our lands in the southwestern part of the island will increase, in some places, more than 100 per cent.
>
> Taking into consideration what has been said above, the future of the Uba cane on a large scale in Porto Rico depends strictly upon the factory.

These data are of great value to the planter on a large scale, not only for the Uba cane, but for the Cayanna No. 10, since they are of the same type.

Through the courtesy of Dr. F. S. Earle, Agronomist of the Central Aguirre, we publish, in the following, some analytical data on this cane; the highest figures, perhaps, known up to the present time, giving the conditions, all favorable, under which it was grown, accounting, probably, for these wonderful results.

Uba cane planted in saline and dry fields, on January 27, 1922, germinated and grew well.

ANALYSES OF THE CRUSHER JUICE

Date of cut	Brix	Sucrose	Purity	Age
2-22-23	20.80	17.43	83.8	Young plant, 13 months
2-23-23	19.50	16.75	88.2	Young plant, 14 months
4-16-23	19.30	17.15	88.9	Young plant, 15 months

The author knows of various cases in which this cane was a disappointment because of its low sucrose and purity, notwithstanding having had sixteen months growth and good cultivation; this I must attribute, perhaps, as being due to continuous rain or to its not yet being matured.

Zwinga

This is another erect cane, very vigorous and a great ratooner, with a long, slender stem (2 cm. as an average diameter) ash-green in color. The internodes are long and completely cylindrical (13 to 15 cm. in length); the nodes are reduced and conspicuous. The rudimentary root bands are much extended outward and from 10 ot 12 cm. in width. The rudimentary shoots are well grown, clustered and conspicuous, and are formed in three to four rows. The bud is somewhat oval, measuring approximately 10 x 12 mm. exceeding in length the width of the root band by one-fourth of its width. The leafsheath has some fuzz, especially on the side. The numerous leaves are of a green color, somewhat inclined (4½ to 5 cm.) and very slightly dentate.

This cane was imported from Louisiana by the Federal Station at Mayaguez. Analyses made demonstrate that it is slower in maturing than the Uba, to which it is very similar, but differs in the abundance of fuzz on the sheath and the protuberance of the nodes. In the Uba the internode and the node are somewhat the same in diameter. Like the Uba, it is free of mosaic and resistant to the diseases of the roots and to gummosis.

As a producer of sugar, this cane has not much value, being slow to mature, and of low purity and sucrose content. In the southern states of the United States it is planted to use as forage for cattle and for the production of honey. It is not very common in Porto Rico, but its similarity to the Japanese cane gave rise to confusion, by planters, between the two varieties.

(Biloxi) Cayanna No. 10

This is another erect cane, very vigorous and an excellent producer, tillers enough, but not abundantly like Uba cane. The stems are long, slender, 1¾ to 2½ cm. in diameter, of a clear green color, like lily leaves, and abundant in wax. The internodes are long, sometimes measuring up to 15 cm., those below becoming more developed than the upper nodes. The nodes are well grown, large, sunken, and measure sometimes 2 mm. in width. The zone or banding of the rudimentary roots is rather wide and grows 10 to 12 mm. and is of a green or mottled color. The rudimentary roots are well developed, with the centers of tobacco color and grouped in three rows. The bud is obtuse-oval, robust, generally measuring 10 x 12 to 14 mm. The skin is of a clear green color, with fine hairs, more on the margins. The leaf or leaf blade is well opened, inclined, 4½ cm. as a general width, of dark green color, slightly dentate toward the base.

This cane has proven to be vigorous, productive and a better ratooner than the Uba or the Zwinga, which it resembles very much. It can be easily distinguished from the other two by the uniform growth of the buds, by the hair that appears on the surface of the leaves, by the robust and well-formed buds, by the fact that germination is subdorsal, while the Zwinga and the Uba are terminal or by the apex. It is more similar to the Zwinga because the two have well-developed nodes and more or less hair on the epidermis of the leaf; but they are easily distinguished by the form of the bud. When the bud is already germinated and begins to form a head, it is always in an erect position, while the Uba stretches and inclines a little. I have observed that the Uba is a little slow to germinate and is therefore tardy in its development and requires as much care and cultivation as any other variety, not succeeding as well as the Cayanna No. 10, with its germination, its uniform and more exuberant development than the Uba and the Zwinga. This is not so when we speak of the ratoons; thus the Uba can ratoon very well, in abundance and with vigor; it is surpassed only by the Cayanna No. 10.

From experiments made by this Station and in the Central Aguirre, this cane has proven to be the best ratooner and to yield more tonnage than the Uba, and, if allowed sufficient time to mature, it would give as much, or perhaps more, sugar per acre as will be seen by the following analyses of the present crop made in the Central Aguirre.

Variety of Cane, Cayanna No. 10. Planted December 29, 1921, with seed brought from the Insular Experiment Station of Rio Piedras:

ANALYSES

Date	Brix	Sucrose	Purity	Age
1-20-23	16.55	13.23	79.8	13 months
2-19-23	16.80	13.64	81.2	14 months
3-19-23	17.80	15.13	85.0	15 months
3-31-23	17.40	15.08	86.6	15½ months
4-16-23	18.00	15.60	86.7	16 months

It is similar to the Uba and to the Zwinga in their industrial and agricultural characteristics, so we deduce that it is also free of mosaic, as up to the present time it has proven to be; but no instance is known of its having contracted such an epidemic.

In the Gran Cultura in 1919, Mr. F. S. Earle received some cuttings of cane sent by Mr. S. M. Tracy from the small town of Biloxi, Miss., U. S. A., and, from the letter written by Mr. Tracy which accompanied said seed, is quoted the following paragraph, relative to the name of this cane.

Mr. Tracy says: "I consider this to be the best of the Japanese canes, of which I have many. It is larger and stronger than the others. The manufacturers of syrup of this community, to whom I gave seed, believe that this is the best cane that has been produced for other reasons. I have lost its name and so I call it 'Biloxi'."

This paragraph, without doubt, shows how this cane came to be given its name, but later on Mr. Earle saw in the Experiment Station of Cuba a cane similar to it, which might possibly have been the same, under the name of Cayanna No. 10, so without doubt that is its proper name.

Chemical results were obtained from an experiment made in the Insular Experiment Station with these three varieties of cane; they were planted in rows five feet apart, on the same date (16-2-21) and in the same parcel of land, in plain rich soil, open and well drained, given the same cultivation and only one application of fertilizer 10-10-0 in the plant crop and in the ratoon crop. The analyses of the plant cane were made in the laboratories of the Central Vannina from the mill juice, and the ratoons were analyzed in the laboratories of the Station with a small mill of three rolls driven by a gasoline motor.

ANALYSES OF CANE

Variety	Age	Unc. Brix	Sucrose	Purity
Japanese	Young plant	.....	13.19	85.92
	Young plant	.....	15.82	86.84
	First ratoon	18.70	17.37	90.00
	First ratoon	16.80	15.74	89.43
Cayanna No. 10	Young plant	.....	9.98	72.00
	Young plant	.....	11.56	77.30
	First ratoon	16.10	14.59	87.37
	First ratoon	16.70	15.75	86.89
Zwinga	Young plant	.....	8.81	69.37
	First ratoon	17.70	15.50	84.47
	Young plant	17.50	15.97	87.99

Of these three varieties, that which is grown most in Porto Rico is the Uba, of which there are eight to ten thousand acres*; the Zwinga follows, with scarcely 500 acres. Of Cayanna No. 10 there are some experimental tracts on the island. The Uba cane is fulfilling its mission on the west and north coast, where the mosaic threatens to destroy the sugar industry. Of Zwinga, there remain but 500 acres. Where the epidemic has spread they have substituted, for the local varieties that were infected, the Uba to such an extent that approximately 2,000 acres of it are under cultivation, which, from results obtained in the field as well as in the mill, is proving satisfactory.

Ground Firebrick for Furnace Repair**

By Joseph Harrington

In the issue of *Power* of January 3, 1922, the writer described the development of a special monolithic furnace lining that was being worked out by James A. Faulkner, who was then the boiler room engineer at the Cleveland Electric Illuminating Company's Seventieth Street plant. This article treated in brief of the utilization of old firebrick bats which, being ground and mixed with a small percentage of high-temperature cement, constituted the material used in the relining of boiler furnaces. It promised not only to be a great economy, but

* Later information shows this area has been greatly extended.
** Power, Vol. 59, No. 25.

involved several interesting phases of high-temperature work. A number of high-set Stirling boilers were relined with this material, with such excellent promise that Mr. Faulkner has since carried the work along commercially to a more extensive degree. It is the result of this later work that should interest combustion engineers generally.

The first result of using old furnace linings that had been partly destroyed was the shortage of old material, and inasmuch as the entire remaining portion of the old firebrick was used without the addition of new material, it early became evident that additional new material would have to be used. This resulted in the development of a plastic bond to be used as mortar in setting up new firebrick walls.

For many years it has been recognized as a cardinal principle in furnace work that the mortar or clay used to form the joints in the brickwork should be of the same chemical characteristics as the brick itself, to avoid having the mortar act as a flux, and in order that its fusing point would be the same as that of the brick. When this basic principle was violated, it was found that the clay joint melted out at a lower temperature than the brick, leaving openings that allowed the furnace gases to attack the brick on more than one face and cause rapid deterioration. Moreover, the clay in its fluxed condition offered opportunity for mechanical attachment of particles of ash blown or lifted from the fuel bed, building up in this way on the side walls a slag deposit that frequently became destructive, the walls suffering when the slag is broken away.

It is almost an ideal situation in which the mortar is made up of the same firebrick as used in the wall itself. Under these circumstances the mechanical and the physical characteristics are identical, and it has been found that a joint so made does not fuse or flux. As a result thicker joints can be made, courses evened up and holes filled in at will without injurious effect and at a much lower expense.

To develop such a product as this, experimentation was required because it had to have a considerable degree of plasticity and at the same time had to set up strongly enough to take the weight and carry the stresses incident to furnace lining. A simple fireclay bond made up of a high-grade clay was not strong enough and had but little plasticity, so that to this base was tried the addition of Portland cement, sodium silicate and other chemicals. Finally a bond that seemed to fulfill all the requirements was developed and it is now being used with success for this purpose.

In connection with the process there developed a mechanical problem that also required attention before it was solved. Hand mixing, no matter how carefully executed, resulted in a sandy product, and when further moistened, the finer parts washed out of the mixture. To render this material permanently plastic, it was found necessary to subject it to the influence of the heavy mullers or wheels of certain familiar machinery used in the preparation of brick. The type of machine is well illustrated in Fig. 1, which also shows a pile of old brickbats removed from furnaces and ready to be ground.

An interesting phase of this work from the financial side, is indicated in the accompanying tabulation, showing the relative cost of brickwork laid up with thin and thick joints.

Comparative Costs of 100 Cubic Feet of Brickwork.

THIN JOINTS

20 bricks per cu. ft.=2,000 brick @ $50	$100.00
500 lb. h. t. cement per 1,000 brick=1,000 lb. @ 4c	40.00
	$140.00

THICK JOINTS

100 cu. ft.—15 per cent requires 1,700 brick @ $50	$ 85.00
1,000 lb. mortar per 1,000 brick=1,700 lb. @ $7.50 ton	6.38
	$ 91.38

A saving of $48.62, or nearly 35 per cent.

It will be noticed from the table that thick joints in brickwork occupy about 15 per cent of the volume, and when this is made up of a material identical with that of the bricks themselves, the product is in effect a monolithic wall, at least so far as its uniform chemical and physical characteristics are concerned.

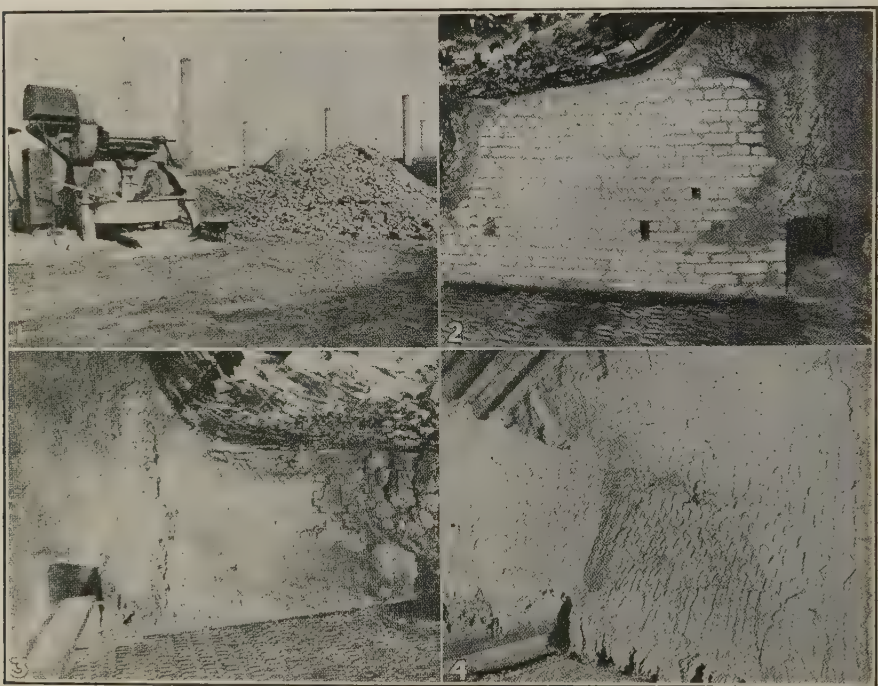

Fig. 1. Wet pan for grinding and mixing the brickbats and special bond.
Fig. 2. Furnace side wall with heavy joints of special bond.
Fig. 3. Same wall as in Fig. 2 after seven months' run.
Fig. 4. Furnace side wall ready for repairs.

Under the former method of relining furnaces when nearly worn out and throwing away the old material, experience shows that an actual wastage of one-third of all the firebricks was suffered. There being room for about 15 per cent of special mortar in the wall, it follows that there will accumulate considerable material unless it is used in quantities for laying up monolithic walls and for similar service, so that there still remains as an interesting phase of the problem,

the ability to utilize the mortar for such work. Also it can be spread over old and partly worn out furnace linings, to which it will adhere and over which it will form a protective coating that can be renewed from time to time with practically no further deterioration of the underlying brickwork. When sufficient material accumulates, the entire bridge wall or possibly an arch can be laid up with this material.

To illustrate, Fig. 2 shows the side wall of a boiler furnace laid up with new firebrick and fairly thick joints. This was a repair job, as evidenced by the appearance of the surrounding parts. After seven months of hard service with practically continuous operation in the vicinity of 250 per cent of rating, the photograph shown in Fig. 3 was taken. It actually shows the opposite side of the furnace, but the conditions were much the same, being satisfactory on either side.

Fig. 4 shows the interior of a boiler furnace laid up in the usual manner before repairs were made. This wall was about ready for complete replacement, but the special material under description was used and laid on with a trowel. It consisted of 80 per cent of old firebrick and 20 per cent of the special bond. The appearance of the wall when the work was finished is indicated in Fig. 5, and Fig. 6 shows the same wall after five weeks' service.

Another side wall that had been in service four months is shown in Fig. 7, and in Fig. 8 a high bridge wall built up as a monolithic structure and photo-

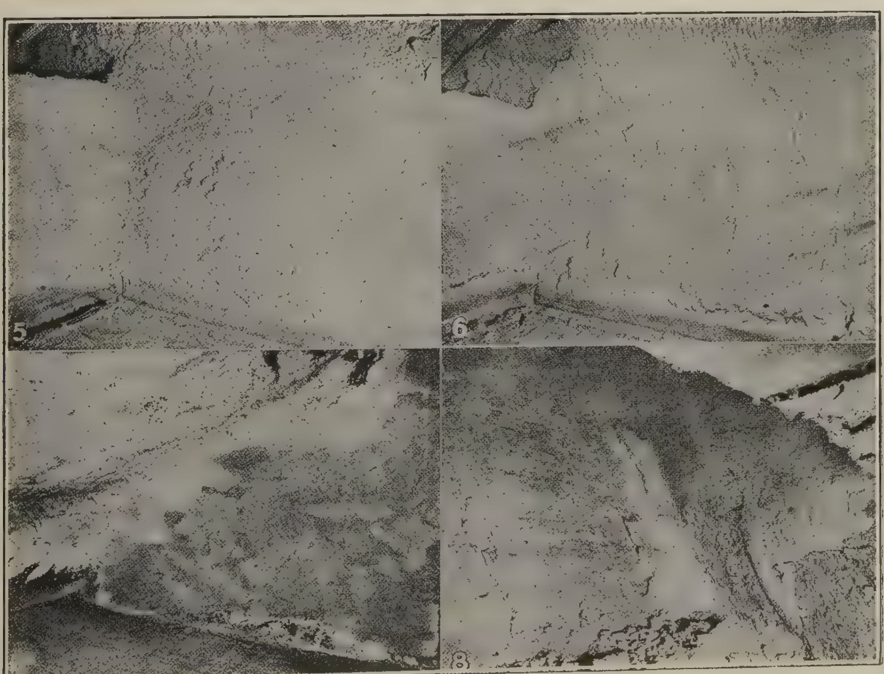

Fig. 5. Side wall of Fig. 4 plastered with refractory mortar without removing old brickwork.
Fig. 6. Wall of Fig. 5 after five weeks' service. Practically unbroken surface.
Fig. 7. Furnace side wall plastered with the refractory mortar.
Fig. 8. High sloping bridge wall of monolithic construction after several months' service.

graphed after several months' service. As indicated in Fig. 9, the bridge wall was constructed by a method similar to that described in the first article in *Power.* Wooden forms were put up foot by foot and the material pounded in place behind the forms, after which the forms were removed and the wall given a slow drying. No attempt was made to smooth up the work.

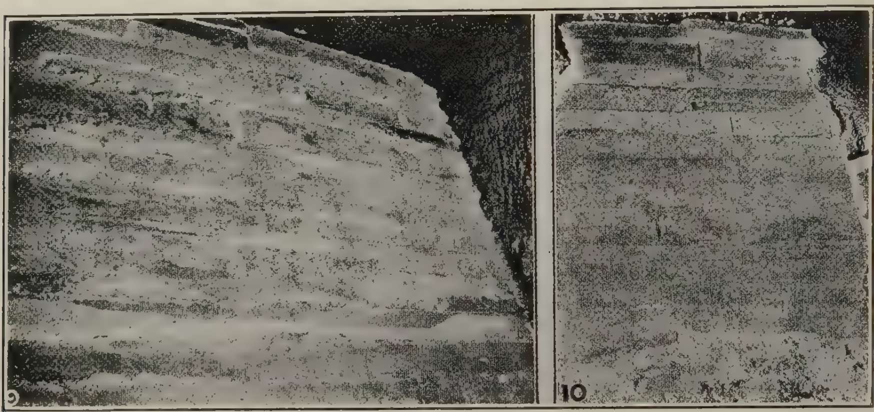

Fig. 9. Method of building bridge wall of Fig. 8 by the monolithic method.
Fig. 10. Patching a side wall with refractory mortar.

A patch in a side wall built up in this way is shown in Fig. 10. It is interesting to note that a large, irregular patch can be applied in this manner and the material pounded in place along the sides to make a joint with the brickwork. Evidently, extensive repairs can be made without any special reference to dimensions or surroundings.

The practical side of these methods lies in their economy, secured through a lower cost per cubic foot in both material and labor, the lessened loss by radiation and infiltration and the longer period between repairs. Anything that genuinely decreases furnace maintenance is worthy of careful consideration.

[W. E. S.]

Experiences in Obtaining Seedlings by Bagging and Artificial Pollination in 1924

By Twigg Smith

As an introduction to a resume of our experiences gained during last year's artificial cross pollination of sugar cane I am giving some extracts from *Anatomical and Physiological Studies Concerning Sugar Cane in Cuba,* by Dr. Eva Mameli de Calvino, Chief of the Department of Botany of the Agricultural Experiment Station, Cuba. Bulletin No. 46, April, 1921.

These extracts are particularly interesting as they coincide in most respects with results established here:

The production of varieties of cane by means of the true seed is rather difficult for various reasons.

(1) Because in all tropical and subtropical regions there are many varieties which bloom rarely and there are others that never bloom at all.

(2) Because causes of sterility until now only partially known affect at times the pollen and sometimes the ovaries so that canes reproduced through spontaneous dissemination, i. e. natural field crosses, are very rarely found.

(3) Because plants obtained from seed are very delicate and die easily unless they are taken particular care of.

At the Agricultural Experimental Station of Santiago de las Vegas, in the year 1920, 585 seedlings were obtained, 17 of them by artificial means. To be used for pollinization the cane was cut at its base and carried with its flowers to the female tassel and brought in contact with the inflorescence. In order to avoid quick fading the cane used for pollinization was placed into a can filled with water, and also, the cane itself was changed every three days. The inflorescences under crossing were enclosed in a cage covered with nainsook. In Cuba this method (bagging) protects the pollen and the stigma from the damage caused by the dew which is heavy at the time of blooming of sugar cane.

The crossings of some well known parents are very difficult to obtain in sugar cane, sometimes because of special characteristics of the flower and the variable fertility of its sexual organs, sometimes because the varieties which might cross do not bloom simultaneously. The castration of flowers, the bringing of foreign pollen, the guarding of inflorescences during pollinization have all given rise to the various methods which I am going to describe.

The System of Alternate Rows

In Java there were obtained many seedlings by planting the cane to act as male in alternate rows with the cane to act as female, using as female the Cheribon cane which is said to have sterile pollen. This method has two causes of error: (1) The sterility of pollen of one whole inflorescence cannot be guaranteed except in very special cases. (2) The paternal relationship is uncertain as foreign pollen may be carried by the wind to the stigmas, except where complete isolation is affected. Pollen of sugar cane is very small (42-46 micrones) and it can penetrate through any texture of cloth, also the wind can carry it a considerable distance.

Emasculation of Flowers

This method gave very little results. The structure of the cane flower does not permit of careful emasculation without lesions to the stigmas and other organs. From a practical point of view this method does not seem suitable.

Bagged Crosses

Various procedures have been modified to the following: the male tassel is cut, placed in a can of water, so that it is above the one to be fertilized, and both are enclosed in a muslin bag. At 10 a. m. the male tassel is lightly shaken to make its pollen fall upon the stigmas of the female tassel.

Collecting Pollen

Another system is of gathering the pollen in the morning after the dew has disappeared, on sheets of paper, or in small capsules of gelatin. Barber says if the pollen is not very dry it will stick and form heaps which make fertilization difficult and he advised to leave these pollen grains exposed to the sun for some time or to heat them (without indicating the temperature) and to pass them through a piece of cloth and apply with a rubber bulb.

Although Dr. Barber points out that the pollen of Sacc. spontaneum will germinate even after two weeks I do not advise drying in the sunlight, heating, or passing through

cloth as temperature, time, and other indispensable precautions cannot be precisely given. Pollen germinates between narrow limits of temperature and humidity, variations in the physical state of the surroundings may harm it, and this explains some of the failures in germination of the flowers of sugar cane after both natural and artificial fertilization.

Crosses Obtained Without Bags

Dr. Barber found that bagging tassels increased the temperature ten degrees over the outside temperature and therefore in India bagging has been discarded for the method of dusting the desired pollen on the stigmas of the chosen female tassel until the stigmas are dry. This method presents the same uncertainties of parentage as the alternate row method for there is no way mentioned of protecting the female tassel from foreign pollen.

Experiments Regarding the Fertility of the Pollen and the Ovary

Numerous works from Experiment Stations in Java and India refer to a method adopted to test fertility of pollen and pistils. The method consists of treating the parts with a solution of distilled water grs. 100; Iodide of potass. gr. 1, iodine gr. 1. If starch is present the parts turn a bluish hue. But that Dr. Barber doubts the universal application of this method can be told from a recent communication of his, a doubt I myself have arrived at in the course of my experimental work. In the communication Dr. Barber says: "The necessity of further studies regarding the value of the experiment as to fertility of the ovaries of the flowerets of sugar cane might be suggested in as far as the presence of starch in the styles is concerned. The discovery of this method was made by Mr. van Katraman but from recent conversation with botanists from Java its universality is to be doubted."

Germination of Seed

The best results in germination were obtained for early tassels; negative results from later tassels. Time of germination 5 to 6 days, in some cases 3, rarely 8 or 10 days. We intend pruning the female tassels, reducing considerably the number of flowers to see if the number of fertile grains is increased.

Critical Examination of the Results

The examination as to starch in the pollen and pistils of cane has compelled the producers of hybrids in sugar cane to examine microscopically the sexual organs of the flowers in order to find the causes of supposed sterility. But it is necessary to point out that some authors at least have established an inexact relation between the germinability and the presence or absence of starch in the pollen and particularly in the styles of many canes. Indeed as can be seen as a result of this study, the presence of starch in the granulas of the pollen is bound to the normal state of the granula itself for the granulas of pollen lacking starch are likewise found to lack all other substances and to be soft. Consequently it is sufficient to find, on examination of the pollen, the presence of the spherical shape and the granular contents; a simple proceeding which also allows the further use of the pollen. As regards the presence of starch in the styles there seems to be according to my observations, no relationship between the fertility of the pistil and starch in the styles, because varieties which, when examined microscopically were lacking in starch in the styles, yet have nevertheless produced fertile pollen both in natural and artificial fertilization. On the contrary some varieties that gave positive results in the observation of starch in the styles produced a sterile seed.

The best conditions of viability and germination of the pollen and the pollinization and the fertility of the pistils can according to my view only be obtained by the observation of the normal morphological organs (spherical pollen full of granulas of starch, ovaries, styles and stigmas that are not aborted or contracted) and this observation alone has practical value.

Conclusions

The methods employed up to the present time of protecting the tassels to guarantee the parentage of the crossings of sugar cane are insufficient. They do not keep out foreign seed, for it penetrates the densest fabrics. Using bags of oiled paper or glass boxes increases the temperature and makes for poor circulation.

It is necessary for each country to study its own conditions of protection, also as regards temperature and humidity.

It seems to me that a glass house in which the work of artificial crossing could be carried on would be of great use, it could be divided in compartments to carry out numerous crossings of different varieties at the same time. By this method the errors inherent to bagging can be avoided, and serious experiments regarding crosses, also the best conditions of temperature and humidity for fertilization can be studied.

The macro and microscopic characteristics of the tassels and descriptions of the different varieties of cane are of the greatest importance both for identification of the varieties, and the selection of better specimens which are to serve in crossing.

The histological study of varieties of cane have revealed noteworthy differential characteristics between varieties and also between closely related canes.

The conditions determining the irregular flowering of cane are unknown. To determine it, it would be necessary to record the relative data as regards temperature, hygroscopicity of the air and soil, etc., during the growing as well as the flowering period.

Pollen from the same variety grown in different places may differ as to its normality.

Pollen of sugar cane does not germinate under common means of cultivation. The stigma of nicotiana tabacum was found the best medium.

It is interesting to note that Dr. Eva Calvino, in the paragraph on collecting pollen, says that in Cuba the pollen is collected in the morning, after the dew has disappeared, on sheets of paper, etc.; and under the heading of Bagged Crosses the same writer states that it is their practice to shake the suspended male tassel at 10 a. m. to make its pollen fall on the stigmas of the female tassel.

A very interesting and important point in connection with cross pollination was brought up by Dr. E. W. Brandes at one of the meetings of the Cane Sugar Section of the Pan-Pacific Food Conservation Conference held here August 1 to 14 this year, when Cane Breeding was discussed. As it has to do with the very commencement of the technique of cross pollination of sugar cane I think it can well be placed in this foreword. Speaking on the subject of "Diurnal Variation in Opening of Florets," Dr. Brandes stated that: "As a result of careful observations made at the U. S. Experiment Station on Lake Okichoki, in Florida, it was found that the florets of sugar cane opened up at about 3:40 in the morning, and from that time on until daylight were in the best condition to receive pollen. "Therefore," continued Dr. Brandes, "all our experiments of cross pollination were conducted during those hours."

So far, in Hawaii, we have not made any experiments to ascertain at what hour in the day or night the stigmas of our cane are most receptive. In the method of tying in tassels we have tied them beside the female tassels whenever they were brought in from the field. The time would range from before daylight to dark. By this method we have been able to secure many hundreds of germinations, but it may be that if we are able to establish a period during which stigmas of sugar cane are receptive to pollen and that for the rest of the day they are not receptive, it surely follows that it would be useless to expect results

during the closed period. This would naturally apply to the brushing on of pollen as well as the tying in of tassels. This coming flowering season we will endeavor to find out the receptive period for our varieties and then by actual experimentation see if we can get more germinations by:

(1) Tying in male tassels, freshly gathered, during the receptive period of the stigmas of the acting female variety.

(2) Dusting on pollen, shaken from desired tassels, during the receptive period of the stigmas of the variety acting as female.

Methods Used in Hawaii

Inasmuch as the hitherto published experiences in getting known crosses of sugar canes have been more or less outlines of systems used without giving details, I am giving here our experiences of this year in full detail wherever possible.

The plan outlined at the outset in the middle of November, 1923, was very ambitious. We wanted to try conclusively on many varieties the use of the bagging method, both for self-pollination and by introducing foreign pollen. Also the method of dusting or brushing on pollen to the stigmas of varieties that were desirable as female parents. We were particularly anxious to use many varieties as male parent with Uba as female.

With Mr. Kutsunai, I made a very complete reconnaisance of Oahu plantations for about a week in November, during which time we noted the location and condition of the varieties we expected to use.

Early Tasseling Varieties

Among the first canes to tassel (November) we noted H 109, D 1135 and Yellow Caledonia in nearly every plantation where those varieties are grown. We found Badila at Puuloa, Ewa, Waipahu and Kahuku, but we found it tasseling at Kahuku only. We located Lahaina in Kipapa Gulch and that variety with H 109, D 1135 and Badila were the only ones that were tasseling in sufficient numbers to make it possible to use the tassels in the method of bagging, or collection of pollen for the brushing or dusting method, Yellow Caledonia being one of the varieties that so far has not produced normal flowers. We did not find any Uba in tassel anywhere excepting at this Station.

Bagging Method

We then had bags or cages made to the following dimensions:

Poultry wire of 1½″ mesh and 4′ wide was cut in pieces 6′ 2″ long and tied to form a cylinder that was 4′ long with a diameter of 2′. This cylinder was strengthened by the addition of No. 6 galvanized wire, one piece threaded perpendicularly with the cylinder and a circle of wire at top and bottom. For the purpose of testing the efficiency of cloth in preventing the entrance of foreign pollen we used three different grades of cotton, one heavy unbleached 90″ wide, one of "Harding" cotton 36″ wide, a medium weight, and one cheese-cloth, a very light open cloth.

We found that the best way to get the cloth secured around the wire netting cage was to make the cotton into a bag first and slip it over the netting, tying it in a few places top and bottom.

On November 19-20, we erected eight cages at Makiki, five enclosing H 109 tassels and two Striped Mexican. Some days later three were put up over Lahaina and two on Hawaiian canes. We used 15- and 20-foot pieces of 2 x 4 for poles, sinking them 3 feet in the ground and found later in many cases even the 20-foot poles were not high enough. We secured the tassels and bags as much as we figured they would stand without breaking the tassels but the heavy winds commencing on the 26th of November and continuing off and on through December broke down the cages, tassels, and in two cases snapped off the supporting 2 x 4 poles, utterly ruining chances of all these experiments excepting two cages on Striped Mexican tassels. These two were pollinated with H 109 (method described later) and 7 seedlings were germinated. On the 20th of November, we erected 5 cages and on the 26th one more at Kahuku, enclosing two young unopened Badila tassels in each cage. We used three grades of cloth on these six cages, two of thick, two of medium, two of thin. Conditions for a test of the possibility of cloth keeping out pollen were excellent. The Badila tassels enclosed were too young to have received any pollen, they were absolutely unopened, while all around were other varieties in full tassel, their anthers hanging out in a great many cases. The variety H 146, which is very prolific and as a general rule has a great amount of viable pollen, was on the windward side. We had thought of introducing pollen of other varieties into the Badila bags, but the location, 40½ miles from this Station, made it impracticable. As a test of the bagging method this experiment should be very good, as the bags were secured top and bottom and with the exception of being opened slightly occasionally for observations, they were not opened until the tassels were brought in for planting on January 11, 1924. The heavy wind and rain mentioned before had demolished all but three of the Kahuku bags, two of the thinnest muslin bags and one of the thick muslin being saved. Commencing on January 17 and continuing for 18 days we got a steady germination from the tassels from the thinnest muslin bags until 122 were counted. From the thickest muslin bag we got one germination which afterwards turned out to be grass. The seedlings that survived through the transplanting have been planted in an effort to determine whether they are Badila selfs or whether foreign pollen was introduced by the high winds prevailing during the period of enclosure of the tassels.

An Experiment to Determine if Pollen Could Pass Through Cloth

Prior to using these three grades of cloth mentioned, we collected some pollen of D 1135, placed it in a large-mouthed container and when we inverted the container over loosely held cloth of each grade, the pollen easily passed through to the table below. This proved conclusively that it was possible to pass the pollen through, but we felt that if any thicker cloth than the heavy unbleached were used on the cages there would be a total absence of light, and consequent weakening of the enclosed tassels. Towards the end of December a cage was erected within the Uba x D 1135 windbreak in which we enclosed two unopened Uba

tassels. Several times H 109 was tied in with the Uba tassels and at least twice the pollen of H 109 was dusted on. The heavy windstorms partially wrecked the cage but on January 8, 1924, we planted the remaining Uba fuzz and between January 14 and 20 there were 7 germinations. Of these one was saved and is numbered in the field as U-H 1. At present it is a promising seedling.

Conclusions on Bagging Method

The experiments conducted using cloth covered cages to imprison the inflorescences are not yet completed, as in the case of the Badila experiment we wish to determine whether the seedlings obtained are selfs, or crosses by wind-introduced pollen. Numerically the germinations obtained in the Badila bags were quite satisfactory, and now that they are planted in the field they are quite vigorous.

However, it should be borne in mind that this good germination was from the cages covered with the thinnest muslin through which vagrant pollen could easily pass. The cages covered by thick muslin did not yield any germination, as was also the case with a similarly covered cage on Striped Mexican, the only other seedling obtained by this method being U-H 1, mentioned before.

I do not feel that the trial of the bagging method this year was extensive enough to give us sufficient data to decide absolutely against its use. We were not properly prepared to cope with the high winds that caused so much damage to the erected bags and their contents. However, compared to the use of windbreaks, the bagging method is very cumbersome.

From our experiment of passing pollen through cloth I cannot feel that there is any guarantee that foreign pollen will not enter the bag.

It is true that in cases as with the thin muslin at Kahuku, large numbers of germinations per tassel are obtainable when using the bags. In fact we had no tassels this year by any means of pollination that compared with the thin bag at Kahuku. So with our conditions at any rate the theory that the enclosing of the inflorescence in bags tends to weaken the germination would appear to be false when the material used is cheese-cloth. Heavy cloth gave no germinations. Dr. Barber, of India, and Dr. Calvino, of Cuba, have very little to say that is good for this method and a great deal against it. In fact Dr. Barber has discontinued the bagging almost entirely, principally because the seedlings obtained were weaklings, due to the excessive temperature in the bag during fertilization. Dr. Calvino finds that none of the methods in use give absolute assurance of parentage and suggests a glass house as the remedy. A glass house could be so arranged that the desired canes to be used as female parents (having previously been grown in pots) could be moved in before tasselling and the pollen-bearing tassels introduced. This method, providing proper allowance is made for ventilation and temperature, should be ideal.

See article *Extracts from Anatomical and Physiological Studies Concerning Sugar Cane in Cuba* by Dr. Eva Mameli de Calvino in introduction to this article in which Dr. Barber is quoted by Dr. Calvino.

Windbreaks

At about the time the wire cages were being made we had windbreaks erected in four widely separated locations at Makiki.

A Description of the Windbreaks: The windbreaks were made of 2 x 4 rough N. W. lumber, used as uprights, with 1 x 3 across horizontally every two feet. They were made what was considered to be sufficiently high above the tassels, about 1 to 2 feet, but next year they will be made higher. We consider now that 5 or 6 feet higher than the highest tassel is not too much, as it keeps the tassels from being wind blown.

Considerable bracing was found to be necessary to make the structure solid on account of the high winds.

This framework was made on three sides only and open at the top.

During a terrific windstorm we put tops on two of the windbreaks, afterwards removing them as the tassels were slowing up in ripening.

The framework was covered with cotton of medium weight and four months after being put up it was in good condition.

Lumber 2 x 12 was placed to form two platforms, one to afford easy access to tie in the "male" tassels and the other, the higher one, so that pollen could be dusted on the stigmas of the female tassel conveniently. Steps were provided to the two levels.

This kind of a windbreak offers no guarantee against the introduction of undesirable pollen by the wind but does protect the female inflorescence and makes the work of artificial pollination by dusting more certain. In this year's efforts we were aided towards certainty in parentage by the location of our cages; also by the fact that Uba, the only cane used as female, was late in tasseling. Again we used as male parents canes, the characteristics of which can readily be recognized in their seedlings. In addition the majority of other varieties had either finished tasseling or the tassels were very old when the Uba experiment was being carried on. If there are any Uba selfed seedlings among this year's seedlings they should be easily recognized owing to the great dissimilarity between the growth habit of Uba and the varieties from which pollen grains were used, H 109, Badila and D 1135.

Varieties From Which Pollen Was Used: Of the four windbreaks three enclosed Uba and one the so-called native or Hawaiian varieties (Manulele, Honuaula and three unknown). The three Uba windbreaks were widely separated and crossed with H 109, Badila and D 1135 respectively. In these three cases we had good success, obtaining germinations from all of them. With the Hawaiian varieties we had no success, as the Manulele flowered but had neither anthers nor stigmas, the Honuaula no flowers, one unknown variety flowered with no anthers and imperfect stigmas, and the rest did not flower. We used two methods of getting pollen to the stigmas of the Uba. We collected pollen and dusted it on and also tied in tassels of the desired varieties. The methods used to collect tassels and pollen will be described under *The Handling of Tassels and Pollen.*

Mending Broken Tassels: In the windbreak where the tassels were within 18 inches of the top we had a great many tassels of Uba bent and some broken off by the wind. That is why we feel that the walls should be at least 5 feet

higher than the tallest tassel. We were able to save most of the tassels, however, by binding splints of split bamboo to the stalk. This had to be done very carefully, winding the string around and around from top to bottom of the splint which was generally about 4 feet long. In cases where the splint was merely tied in three or four places it came loose again and in some cases the tassel was broken in another place.

Bamboo Found to be Best For Tying in Tassels: We made the mistake of using wire stretched from end to end and across the framework hoping that it would support the tassels, and in some cases tying the tassel to the wire, but found that most of the tassels that were broken were snapped off where they crossed the wire, so that method was discontinued. After trying many ways we found that the use of bamboo poles, secured upright, to which the female tassel was fastened, offered the best means of getting the male tassel in proximity, as the can to contain the male tassel could be tied to the bamboo pole also. The platforms were also of great use in changing the water in the cans containing the male or pollen-bearing tassels.

Conclusion on Windbreaks: Next to a glass house where complete isolation of the female tassel can be obtained, I believe this method of using a windbreak to offer the most satisfactory condition for getting quantities of fairly definite crosses.

The element of foreign pollen being blown in by the wind is not eliminated but if care is taken to enclose the cane that is to be used, before the arrows have shown, the chance of definite data is greatly improved. Naturally, it would be unwise to use the pollen of different varieties in the same windbreak.

The Handling of Tassels and Pollen

As a result of our work of this year I am going into detail about the methods we used and the difficulties encountered in the handling of the tassels and collection of pollen for artificial pollination. Generally it has been stated by writers on this subject that the "male" tassel is cut in the field and placed near the "female" tassel. Dismissing the operation in that manner is permissible if all the minor controlling features are well understood. The methods we used to carry out that simple operation are the ones we adopted after many disappointments and failures.

(1) As the successful cross pollination of cane naturally is controlled by the available material and as cane is very capricious in its tasseling it is well to lay out plans according to the available tassels some time ahead of the season of tasseling, which is very limited.

(2) Having located a sufficient quantity of the desired variety, examine its pollen to determine its viability either by the iodine test, using about 1 per cent iodine to 100 c.c. water to detect the presence or absence of starch, starch being present it will turn brownish black, or by microscopic examination to see if the pollen is spherical and contains granulas, in which case it nearly always contains starch. Neither of the two methods are absolute, but without starch the pollen is not of any use, so perhaps a combination of both methods is best.

(3) There must be some opened anthers as well as unopened or immature ones, proving that it is possible for them to open. In some varieties the anthers

do not open although they hang out on the filament. Young tassels are the best as they have more unopened anthers and therefore offer the best chance to get a quantity of pollen. The riper anthers will very likely be shaken and emptied in transit. A normal anther when it is ready or about to shed its pollen is full, well rounded, with the top opened or about to open. The shrivelled anthers are either emptied or if any pollen is still adhering to the sac it is shrivelled or sticky and of no use.

(4) Cut the stalks long, 10 internodes are not too many. This is absolutely necessary as the life of the tassel depends on it. A young tassel, as in one case with Badila, may give pollen for 8 or more days if it is kept alive. Perhaps by cutting an internode a day the life may be prolonged. We did not try that, however. Remove all the leaves clean to the attachment of the sheath. This also helps conserve the energy. If the stalks are to be carried far, lay them out on the ground neatly and wrap up the tassels in flour bags or, better, a piece of 36″ wide cloth about 10 feet long. Tie the stalks securely, but not enough to bruise them. Then attach to a strong bamboo pole of suitable length, we used 8′, set the butts in a bucket of clean water, and if an automobile is used, place the bucket on the running board and secure it. The bamboo pole, not the cane, should be tied securely to the auto top or sides and it will take off all the jar on the journey. To prevent spilling the water place a loose piece of cloth or a flour bag in the water.

(5) The tassels are to be used either to collect pollen for artificial pollination or to be tied next to a variety that is to be used as the female parent, and thus bring about natural pollination. In either case having arrived at their destination the cane must be cut again higher up the stalk, generally by one internode, while the cane and the cutter are under water, in order that the newly cut stalk will absorb moisture and not air. It does not appear to make much difference to the life of the stalk whether it is left in the same water in which it was cut or shortly after being cut transferred to cleaner water.

(6) As it is the pollen in the unopened anthers that is to be used as it ripens and falls, every effort must be taken to keep the stalk alive. It is absolutely necessary to change the water at least twice a day.

The Dusting or Brushing Method: To collect the pollen for dusting or brushing on the stigmas of other inflorescences we did as follows: The stalks having been cut off by one internode while under water as described were left in the bucket of water and leaned against the edge of a table so that their tassels remained suspended over the table on which black glazed paper had been placed. As soon as pollen showed, generally not before 24 hours, it was swept up with a soft camel's hair brush and placed in a container having an air tight cover. Then as quickly as possible the pollen was taken to the tassel to be pollinated and carefully but liberally brushed onto the stigmas. With a hand lens the pollen can be seen on the stigmas if the operation is successful. To successfully take the pollen the stigmas should have a soft, wet appearance. It is useless to brush pollen on an old stigma. If it is a particularly windy season the operation of pollinating must be protected by some kind of screen in or behind which the operator can work, as the pollen is microscopic and easily blown away. In our

experiments this year we were protected by a windbreak which served the double purpose of protection from wind and pollen of other varieties.

The Method of Bringing Tassels in Contact: With this method of pollination we proceeded as follows: Having cut the cane under water as mentioned before we placed its butt in a bottle or can of water suspending the tassel so that it was above and close to the tassel which was to act as female. It was left there for some days with frequent changes of water and when it appeared too old a new one was inserted. We found that the best way to suspend the tassel was by the use of long bamboo placed so that the two tassels would be together and tied to any convenient fixed object. We used mostly the staging of our windbreak. A number of the female tassels were broken as a result of being tied too tight, or of using wire as a support. There must be some give to the stalk or it will break. A little time spent making it right at first will save a lot of worry afterwards.

Time of Collection: Mention has been made in some articles on the subject that the tassels from which pollen is to be gathered must be gathered early in the morning before the dew has disappeared.

We found as a result of collecting at hours starting from early in the morning, five o'clock and at intervals during the day and late in the evening, that it was possible to get the same amount of pollen regardless of the time of collection. The quantity of pollen yielded by the same variety, but growing in different locations at different levels, and under different irrigation conditions varied considerably. We were able to get plenty of good spherical pollen from D 1135 and H 109 growing at Puuloa which is a very low level, and failed absolutely at the same time with the same varieties growing at Waialua at a high elevation. We feel that another contributing factor is the fact that the cane at Puuloa was being dried off preparatory to harvesting while at Waialua the usual irrigation conditions prevailed.

We feel that this factor of irrigation is a very important one regardless of one contradictory case where a tassel brought in from Waipio and under normal irrigation, yielded more pollen and for a greater number of days than any other variety collected. This tassel was of Striped Mexican and was on the table giving pollen for 10 days. It might be well to add that this tassel was handled in a very careful way. A bucket of water was taken in the field and as soon as cut the tassel was placed in water, and the cut end kept continuously immersed afterwards.

Another place where the effect of this factor of irrigation was noticed was with Badila from Kahuku. For a time although great care was taken we did not get pollen, and later, irrigation being shut off for harvesting, the pollen came plentifully, in one case one lot of 10 tassels yielded for 9 days steadily.

Number of Applications of Pollen: It has been stated by some authorities that it is sufficient to artificially pollinate a tassel of cane three or four times. However, as there are thousands of stigmas on one inflorescence, and the stigmas are not all ready to receive pollen at the same time, the thought is that some chances of pollination would be overlooked so we continued pollinating as long as the stigmas remained moist although generally we were halted by lack of male material.

Germination and Care of Artificially Obtained Seedlings of Sugar Cane

The time to cut the pollinated tassel of sugar cane for planting cannot be exactly stated in writing. It requires an experienced eye to get the tassel at just the right time. Roughly, however, it may be said that as soon as the very top florets commence to be blown away it is safe to cut most tassels. We planted tassels at many different degrees of ripeness this year and got good results from all of them. We planted tips of tassels that had been broken off and were hanging by merest fibres, apparently dead, and got good germination. The daily record kept by me during the germinating period, shows that one tip, broken off by wind, and planted December 31st gave 8 germinations from January 8 to January 20. Again, one tip broken off by wind, planted December 31, gave from January 8 to January 21, 63 germinations. In fact a summary of the germinations shows that 216 germinations were obtained from broken tips and broken tassels.

Methods Used For Germination: At the beginning of the planting season we invariably placed a layer of black sand about three-fourths of an inch deep in the glass house flats and filled the flats to about 1″ from the top with garden soil. Afterwards we changed to bringing the soil flush with the top edges, as in that way the flat received the maximum amount of light and no shadows were cast. With the first mentioned method the first place where green algae showed was always at the edges and it was felt that light would help that condition.

The soil used was a good grade of garden soil, which with the boxes had been thoroughly sterilized.

The tassels were cut and in a protected place stripped of their fuzz which was then laid on top of the soil in the flats and thoroughly wet down. We kept the fuzz very wet the first few days. Here is where the drainage question enters.

It has in previous years been found that the best germination comes when the fuzz is merely laid on top of the soil, not buried or covered. The soil acts as something organic on which germination takes place, the object being to keep the fuzz wet but at the same time have the water drain from the flats. Naturally if the fuzz ceases to be moist germination stops. Towards the end of the season we changed the proportion of the contents of the flats to ⅞ rock and sand to ⅛ soil, but as the tassels used were late ones, the fact that we did not get any germinations does not mean that this method is at fault.

We intend using those proportions from the start next year.

As stated before, the heavy winds and generally stormy weather during December and January caused a great deal of damage to the tassels and had we thrown away the broken tips of tassels our total germination would have been cut well below 50 per cent.

Uba as Female Parent: Our experiments this year narrowed down to using Uba as a female parent with D 1135, H 109, Badila, and Lahaina as possible male parents. The experience of last year seemed to show that Uba was an extremely delicate plant from which to obtain germinations. We therefore had a glass house erected and all the Uba tassels were germinated in that glass house. Our first tray of fuzz was placed in the glass house on December 31 and on January 8 the first germination appeared. From then on our troubles began. At first the glass house was simply closed at night, leaving good ventilation, and we got

good germination, then germination ceased absolutely for about one week, and the tiny plants which had germinated began to show signs of weakness.

Green algae commenced to appear and later a few of the plants seemed to be attacked by a leaf disease which manifested itself first by the tiny leaf curling inwardly and then dying gradually from the tip of the leaf in.*

There were, however, none of the usual symptoms of damping off, that is, where the stalk becomes weak just above the soil and topples over.

Heating the Glass House: It was suggested that the possible error was in permitting the delicate seedlings to become chilled at night so we tried two methods of heating in an endeavor to hold the temperature at or near the dew-point of the day. Humidity then became our enemy. It became a question of how much ventilation could we have and at the same time maintain the temperature and a low relative humidity. We tried and discarded kerosene heat fearing that the burning oil generated carbon monoxide which would be injurious to the plants. We next installed electric heaters and it was fairly easy to keep the temperature to about 60° F., while it registered as low as 51° F. outside.

The glass house not having been built with the idea of installing a heating system made it necessary to maintain a watch night and day for a couple of weeks during which time accurate records were kept every hour of the temperature, relative humidity and dewpoint. There was no appreciable improvement in germination as a result of this treatment nor was there any less algae formed. In fact I question the advisability of maintaining even a temperature of 60° F. at night by artificial means. It appeared to retard the growth of the seedlings that had germinated, as even with apparently good ventilation it was difficult to keep the relative humidity down. For instance, a checking of the record sheets shows that, on the average, while we started at the closing up time of the glass house with a relative humidity of around 70° it invariably went as high as around 90° by 1:00 a. m. This increase was caused at times by watering, which was necessary from time to time.

I believe the use of a heating system for our local conditions is advisable for only the few fairly cold nights during January, and that the glass house should

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* In this connection Mr. Lee remarks:

You may recall that several weeks ago you suggested trying out Bordeaux dust for the control of green algae upon the nursery flats and pots.

Tests made with Bordeaux dust show that the algae are killed off and the effect is permanent for at least two or three weeks. Treatments with calcium hypochlorite were not as successful, due to the fact that the hypochlorite did not dust properly and therefore was applied in solution and although the algae were killed the effect was only temporary.

In the successful results with Bordeaux dust on the seedling flats that were tried in the tar paper pots in which H 109 seedlings were growing, the dust entirely controlled the algae very effectively and there has been no visible effect of any sort upon the young seedlings themselves.

Undoubtedly working with this dust new developments and a more exhaustive idea of the possibilities of the dust can be obtained.

be used more as a protection from wind and rain and an aid to germination only. After a fair amount of germination has taken place, say five days after the first germination, I would advise taking the flats outside and treating them like other seedlings germinated from field or natural crosses.

When the algae first appeared we removed several flats, on which some germination had taken place, out into the open. These did not suffer apparently, in fact a few of them are now planted out with the others in fields. For example, we have U-H 4, a hybrid of H 109 and Uba.

At one stage when many of the germinations were succumbing to glass house conditions and the rest were weak and not growing, we moved most of the flats to the open and left them out day and night. We then commenced transplanting to paper pots, figuring that the change of soil and environment might save most of them. A great many were saved, but perhaps two hundred germinated and died without growing appreciably.

Paper Pots: The paper pots referred to were made of a piece of thin roofing paper fastened to form a cylinder. There was no bottom. The best method of filling was found to be cane trash at the bottom for drainage, then one-half soil, and one-half very old stable manure to the top. It is best to bring the soil to the very top as with the glass house flats.

In comparison with seedlings of other parentage and which were germinated in the open, these seedlings of Uba obtained in the glass house were very slow in growth. There was a long period after transplanting to paper pots when they did not change for days. A large percentage of the germinations turned out later to be grass. It was a matter of much speculation for many days as to whether many of the tiny plants were or were not cane. Mortality was high even after transplanting. We had over 500 germinations of which about 80 were grass. We saved and have planted 114, the rest died either in the glass house flats or after being transplanted to paper pots.

At one time, in an effort to control green algae, we used tar paper as mulching paper in the paper pots. This was not successful, the heat germinated under the tar paper caused the tiny plants to wilt at once, a condition very similar to damping off. The plants all revived after the paper was removed. Perhaps the biggest factor in hastening the development of the seedlings was the use of nutrient solutions, as follows:

0.328 grm. calcium nitrate to 1 litre distilled water,
10.0 grms. calcium phosphate to 1 litre distilled water,
Each application was 10 c.c. calcium nitrate solution and 5 c.c. calcium phosphate.

This was applied at weekly intervals to all seedlings with good results.

Summary

We proved undoubtedly that the good germinations come from the early tassels; in fact, from tassels planted after the middle of January, we did not get any germination, although several varieties were still capable of giving pollen which apparently was viable. This condition makes it necessary to concentrate on the early tassels, November and December.

Throughout the whole operation of obtaining seedlings by artificial means the greatest care and attention are necessary.

From the time the fuzz is ready for planting to the transplanting in the field some one must be constantly on the watch for any slight change.

A constant search for insects must be kept up at all times.

We have recorded the appearance of each of the seedlings, plus a photograph of it, at transplanting time, and will continue to add field notes from time to time to see if the peculiarities of the young plants carry through to maturity. Also it will be interesting and valuable for selection to find out if there is any relation between width of leaf, method of growth, and whether upright or recumbent, etc., in infant canes, and, later, their sucrose content.

A Preliminary Study of the Pamakani Plant (*Eupatorium glandulosum* H. B. K.) in Mexico with Reference to Its Control in Hawaii

By H. T. Osborn

[The native name, Pamakani, has been applied to an introduced plant of the thistle family, which first made its appearance as a weed in the country around Ulupalakua on Maui. Like most plants of the thistle family, it produces an abundance of seeds equipped with sails of fine hair or pappus. These seeds are distributed far and wide by the wind, so the plant spreads over the country with astonishing rapidity. In the vicinity of Ulupalakua, it now covers thousands of acres, to the almost complete exclusion of all other plant life. It is a rank-growing, much-branched plant, attaining a height of five or more feet and forms tangled brakes into which man and stock can penetrate with great difficulty only. It has proven to be quite unpalatable to grazing animals and so has become a most pestiferous weed on the ranch lands. It has spread to the ditch country on windward Haleakala, to Iao Valley on western Maui and to the islands of Lanai, Molokai and Oahu, on each of which it has become thoroughly established. Iao Valley evidently affords conditions very much to its liking, for it has reached high concentration at many points and completely covers steep slopes which previously were quite devoid of vegetation. Its behavior in this locality seems to indicate that it might perform a useful function as a ground cover on some of our watersheds.

This Pamakani is a native of Mexico and was early introduced to the horticultural trade as an ornamental flowering plant. It produces showy, compact clusters of white flower-heads which closely resemble those of the well-known Ageratum. Its proper name is *Eupatorium glandulosum*, but it has been offered in seed and plant catalogues under the names *E. adenanthum*, *E. adenophorum*, *E. americanum*, and *E. trapezoideum*. It is now extensively grown as a garden

plant in Bermuda. In Jamaica, it escaped from cultivation many years ago and is now widely distributed over that island.

It is only reasonable to suppose that Pamakani was brought to Maui in the early days as an ornamental plant. The soil and climate evidently fulfilled its requirements and not being restrained by any disease, insect pests or grazing animals, its efficient equipment for spreading and its natural competitive powers enabled it to quickly appropriate to its own use large tracts of land. At the present time, its control on the open range is one of the most serious problems confronting those ranch lands which have been invaded.—H. L. Lyon.]

My attention was first called to the occurrence of the Pamakani plant, *Eupatorium glandulosum* H. B. K., on the islands of Oahu, Maui and Molokai, in a letter dated May 22, 1923, which I received from Mr. H. P. Agee, Director of the H. S. P. A. Experiment Station. Because of the serious results occasioned by the invasion of this plant on certain of the ranches on Maui, he requested that I make a thorough investigation of the occurrence of the plant in Mexico and the extent to which it is troublesome on Mexican ranches and to report upon the possibilities of controlling it in Hawaii. First: By the introduction of parasites along the line used in the control of Lantana in Hawaii. Second: By suppressing it with hardy plants which would have value as forage. This project not to take precedence over the work that I was engaged in at that time.

An herbarium specimen of the plant was sent me from Hawaii together with botanical references to the species as a native of Mexico. The following locality reference from the Biologia Centrali-Americana, Vol. II, was given:

EUPATORIUM ADENOPHORUM-SPRENG.

Eupatorium glandulosum, H. B. K.: South Mexico, between Carpie and Gasave, 8200 ft. (Humboldt & Bompland), Costa Rica, Angustura (Polakowsky).

At the time that I received this letter from Mr. Agee I was located at the Hacienda El Potrero, a sugar plantation about 60 miles from Vera Cruz. I was engaged at that time in various insect studies that might be of value to Hawaii, but mainly in the search for and study of the parasites of the army worm (*Heliophila*) and of a sugar cane beetle borer (*Sphenophorus incurrens*) and in an effort to secure such parasites for shipment to Hawaii.

A search was immediately made for this plant in the vicinity of El Potrero but nothing closely resembling the herbarium specimen at hand was observed; and, in fact, my first inkling as to the localities and situations in which to search for the plant was made while in Mexico City, in October, when I was shown herbarium specimens at the Museum of Biological Investigations. Several specimens there were labeled as from the barranca of Cuernavaca and one from wet rocky ledges near Guadalajara, Jalisco.

Plants were first located in the field at Cuernavaca, Morelos, in October, and after once seeing the plants growing in the field it has been a very easy matter to locate them if present in any locality visited.

I have been located in, or visited, the following localities in Mexico during the past year. During June and July, I was at El Potrero, Vera Cruz. During the latter part of July, I visited the Hacienda Atencingo, a sugar plantation in the state of Puebla. In August, together with Mr. Van Zwaluwenburg, Entomologist for the United Sugar Companies, I visited several sugar plantations in the state of Colima. From there we went to the Isthmus of Tehuantepec visiting several plantations in the vicinity of Tehuantepec and San Jeronimo. We were back at El Potrero, Vera Cruz, the latter part of August. During September and the early part of October, together with Mr. E. G. Smythe, of the U. S. Bureau of Entomology, I was at Cuernavaca, Morelos; Oaxaca, Oaxaca; Orizaba, Vera Cruz, and at Mexico City. From October 17, until November 8, I was at Cuernavaca. November 12, I left Mexico City for Los Mochis, Sinaloa, spending a few days in the vicinity of Guadalajara, Jalisco, and also stopping off en route at Tepic in the state of Nayarit. I was at the United Sugar Companies, Los Mochis, Sinaloa, during the winter months, returning to the vicinity of Mexico City the first of April, 1924. Since returning to this part of Mexico, Cuernavaca has been visited twice, the first and last weeks of April. A stop was made at Orizaba and at Cordoba, Vera Cruz. A short trip was made in May to the low coastal plain about Vera Cruz, to Alvarado, Tlacotalpan and the sugar plantation of San Cristobal near Cosomaloapam. Two weeks in April and two in May were spent at the Hacienda El Potrero in Vera Cruz. During the past three weeks I have been located at the Hacienda Atencingo in Puebla, the sugar plantation of Mr. W. O. Jenkins, and have also visited Cuautla, Morelos, near by, twice.

My plans in visiting these various localities have been largely made in relation to other projects, and, as it has turned out, for fully two-thirds of the time during the past year I have been in localities in which so far I have not found the Pamakani to be present. The longest consecutive period devoted exclusively to study of the Pamakani and particularly to the insects occurring on it was from October 17 to November 8, at Cuernavaca. From the observations made at this time, however, and from time to time since, it is possible to present the following information regarding Pamakani in Mexico.

I. Occurrence in Mexico—Localities Where Found

The Pamakani plant has been collected or observed in Mexico during the past year in these localities: Cuernavaca, Morelos, 4,500 ft. elev.; Cuautla, Morelos, 4,200 ft.; Guadalajara, Jalisco, 5,000 ft., and the neighboring Barranca de Oblatos, 3,000-5,000 ft.; Santa Ana and San Marcos, Jalisco, Ixtlan, Nayarit, Tepic, Nayarit, 3,000 ft.; Orizaba, Vera Cruz, 4,000 ft.; Atencingo, Puebla, 3,300 ft.

It does not occur in the Valley of Mexico, 7,000 ft., nor did I find any signs of it in any of the surrounding country or at Carpio, Mexico, 7,000 to 9,000 ft.

It was not found on the coastal plain of Sinaloa in the vicinity of Los Mochis. Neither have I found any of the plants in the hot, coastal plain of Vera Cruz. It has not been found at Potrero, Vera Cruz, 1,800 feet, or at Cordoba, 2,700 feet.

In Colima, 1,500 to 4,000 ft., and at Oaxaca City, 5,000 ft., it may quite likely occur, though I did not locate plants at the time I was there. At that time

and when on the Isthmus of Tehuantepec I was not acquainted with the characteristics of the plant and its appearance in the field and might easily have overlooked its occurrence.

The localities in which the Pamakani plants have been found are all in what is known as the *tierra templada* or temperate land of Mexico, and it is reasonable to suppose that they can be found in any favorable situation within this region. They quite likely occur at lower elevations in some localities but in the vicinity of El Potrero, a region with which I am very familiar, I have been unable to find them in any sort of situation at elevations from 1,500 to over 2,000 feet. Hardly 20 miles away at Orizaba, 4,000 feet, they do occur.

The *tierra templada* is that even-tempered intermediate region of Mexico lying in general from about 3,000 to 6,000 feet elevation. The yearly average of temperature is said to be from about 73° to 77° F. and there is but little variation with the seasons. There are two seasons, the short season of moderate rainfall during the months of June to September and the much longer almost totally dry season from October to May. The country in general is mountainous, somewhat sparingly forested on the steeper or higher slopes and with large areas of grass-covered plains and hillsides, which present a barren appearance throughout the dry season. Cactus and mesquite are common in the drier districts. Stony outcroppings are numerous and many deep barrancas or gorges, are cut through the solid rock.

Sufficient rain falls throughout most of the region to produce a crop of corn during the summer months. Most of the valleys are abundantly supplied with water for irrigation from permanent streams and large springs, and here sugar cane, bananas, avocadoes, corn and numberless other semi-tropical and temperate climate products grow continually.

To a certain extent the district about Orizaba in Vera Cruz differs from the rest of the *tierra templada*. It is in a deep valley on the permanently green and heavily wooded eastern slopes of the mountain of Orizaba, a district of heavy rainfall in the summer and of occasional rainy periods throughout the year.

From the fact that the Pamakani in Hawaii has spread over ranch land, in places, to the exclusion of all other vegetation I naturally considered that it would be found in such places in Mexico, under similar conditions. Such has not proved to be the case.

They have been found only in very restricted areas and always in wet places; usually shaded or partially shaded as well. Along small streams they grow in places along the water's edge, usually in small gulches and often clinging to the walls of ledges continuously moistened from seepage or from the spray of waterfalls. Perhaps their habits are most strikingly brought out in their adaptation to more or less artificial situations, such as mill-races, dams, walls, ditches, and aqueducts of masonry construction. In Morelos, there are many irrigation systems, fed by the permanent streams or by large springs. At the sources these are often in barrancas, and where they carry water continuously they are almost certain to be fringed in places at the water's edge with Pamakani. As a rule the ditches are of brick or stone and plaster and in bad condition. The wet places from seepage from the ditches are often also grown up to Pamakani, and where the

water is carried across gulches by the characteristic massive arched aqueducts the plants will be clinging to the outside walls where these are permanently moistened from seepage. Once the ditches are carried out into the open country the Pamakani plants tend to disappear and in the unlined field ditches are superseded by masses of grass and weeds.

The plant does not occur ordinarily along the banks of the larger streams where subject to change of water level, shifting sands, and frequently overgrown with a mass of other vegetation.

In not one single case has a plant been seen in a cultivated field or pasture.

At Cuernavaca, the Pamakani plants were first observed at the end of the rainy season—mid October. At that time plants of various sizes occurred from a few inches up to two or three feet, some bushy plants being possibly of more than a year's growth. None were in flower. At this time the surrounding hillsides were fast drying up. In addition to the most characteristic localities, plants were observed here growing in some more open situations, roadcuts, stone quarries and walls. On my return in April most of these plants had dried up but some had already flowered and produced seed before their underground source of water failed. Along the streams and ditches and aqueducts the plants were in full bloom on my return in April, and again the last week in April, a time by which the great mass of plants had gone to seed, there was one place, a masonry ditch in a barranca where the plants were still in full bloom and still forming buds.

At Guadalajara, in November, a few partly grown plants were observed along a stream at the edge of town. About five miles distant is the deep Barranca de Oblatos, a canyon a mile across and some 2,000 feet deep. Vigorous clumps of Pamakani were growing along the water's edge in the concrete ditch near the intake for a power plant. Lower down where the canyon widened out and the ditch was more in the open, no plants were growing nor were any found along the edge of the river and some of the small streams running into it at the bottom. In climbing out of the canyon a few plants were found, less than a dozen, in wet spots along the trail and a few clumps at the edge of a waterfall near the rim of the canyon wall. They were not in flower at this time.

At the Hacienda Bella Vista, a sugar plantation at Santa Ana, Jalisco, some 40 miles from Guadalajara, a few plants were found growing along a ditch and also a few clumps clinging to the walls of an old stone quarry.

From San Marcos, Jalisco to Ixtlan, Nayarit, the trip is made on mule back, some 60 kilometers through the mountains, and from Ixtlan to Tepic, Nayarit, by auto stage. At San Marcos, a few Pamakani plants were collected along a rocky stream and boulder fence at the edge of town and a few more observed as we got down into the valley near Ixtlan, and also along the stream bank near town. At Tepic, no plants were growing in the flat cultivated valley about the town. Several miles down stream, however, the valley narrows to a deep gorge. A few plants were observed along a ditch in the grounds of a cotton factory about two miles from town. Farther down, a large irrigation and power ditch is diverted just above a waterfall. Clumps of Pamakani occur along this stone and brick ditch at intervals for a distance of several miles.

At Orizaba, Vera Cruz, no plants were observed along the streams or ledges about town, nor in the valley for several miles above town. A few were observed clinging to the walls of buildings near the main street where these were moist from the spray of a waterfall and clinging to the walls of a viaduct by which one of the main streets is carried over the stream in the center of town. At Escamela, several miles distant from the valley, clumps were growing along an old mill-race and clinging to a stone bridge. In the vicinity of Orizaba, many seemingly very favorable situations for the Pamakani occur but which are occupied with other vegetation. The presence of Pamakani might very easily be overlooked. On the mountain sides above Orizaba, within a few miles, are pine forests, while below, one soon encounters a region of very heavy rainfall with a mass of permanently green vegetation.

At Cuautla, Morelos, the Pamakani is present but in very small amount. While in the same general region as Cuernavaca, it is at several hundred feet lower elevation and in a broad valley. A few clumps of the plant are growing along shaded ditches and on a massive aqueduct about a mile from town. A built-up brick reservoir also had plants growing along the sides and a shaded road with a stone fence and adjoining ditch also harbors some. Another situation with Pamakani is a cut under the railroad, dripping wet from the surrounding irrigated fields. A few were in flower the last week in May, but the tips have since died back. I have not found the plant here along the streams or ditches in the open valley, banks of these being smothered in a growth of grasses, weeds and vines.

Atencingo is an irrigated sugar plantation of some 6,000 acres, in an otherwise barren valley. At Chietla a few miles away, bananas, avocadoes, and mangoes are also grown. The source of water for the sugar cane is a small river which runs the entire length of the plantation. At the lower diversion dam about a dozen Pamakani plants were growing. At the upper diversion dam just one Pamakani plant was growing at the intake. Along the main ditches Pamakani plants occurred for a short distance in one place where the canal ran along the shaded river bank and again where a main ditch went through a cut some 15 feet in depth. No plants were observed along any of the open field ditches.

Observations were made along the river for a distance of several miles but only in two places were Pamakani plants seen. One of these was near Chietla where the river cuts in under a cliff. The face of the cliff, about 40 feet high, is continuously moist from seepage of the ditches above, and for a distance of a couple of hundred feet the vegetation is largely Pamakani. The other, lower down, consisted of a single clump of a half dozen plants and was growing along the stream on a sand bank in a deeply shaded spot. There was one cluster of flowers at this time, June 1. Apparently Pamakani does not flower freely here, though the observations were made perhaps too late.

Of these places thus mentioned briefly, it is perhaps at Cuernavaca that the Pamakani habitats are most typically represented. This sloping region is cut by numerous deep gorges with many situations favorable for the Pamakani. Even within the limits of the town are springs, streams, aqueducts, and barrancas,

every variety of situation, in fact, in which to expect Pamakani, and offering ideal conditions for its study.

Here, in the spring, when most of the country is dry and barren, the Pamakani plants reach their full growth and present in contrast to their surroundings a striking appearance with their masses of white flowers.

Plants are probably in flower as early as February, reaching the height early in April and continuing on to the advent of the rainy season in late May and June.

II. Importance of Pamakani in Mexico

From the nature of its occurrence, the extent to which the Pamakani is troublesome on ranches in Mexico is self-evident.

It is of no economic importance whatsoever.

III. Enemies of Pamakani

Insects. Upwards of fifty species of insects have been observed to attack Pamakani in the different localities studied and of this number nearly all have been observed at Cuernavaca. A few species have been found constantly associated with Pamakani, though in several cases observed to attack other plants as well. It has not been possible to rear through to adult a very large proportion of these species and in fact some are represented by single specimens. The material secured together with plant specimens and some insects from related plants were forwarded to Honolulu but as no identifications have yet been received it is necessary to mention them in general terms. To secure adult specimens of most of these insects a much longer time would be necessary in rearing work than I have had available.

Insects attacking stem—

A snout beetle—adults, larvae and pupae, Cuernavaca, October—mines out the stalk at base so that it breaks over. One plant only.

Cecidomyid—forms slight swelling near base of stalk—in several situations; very slight effect noticed on plants. Cuernavaca, Oct., Nov.

Hymenopter—work hardly noticeable on exterior. Cuernavaca, Oct., Nov.

Lepidopter—bores along center of stalk at base; about a dozen bored plants observed—larval stage only secured. Cuernavaca.

Trypetid gall—affecting stems near tip; a few are apt to be found in any clump of Pamakani in the localities studied. It sometimes causes a dwarfing of the plant beyond the gall but usually the plant does not appear much injured. The species is heavily parasitized, all rearings so far yielding parasites. Cuernavaca, Cuautla, Atencingo, Tepic, San Marcos, Orizaba.

Snout beetle—One larva causing stem wilt in new growth. Cuautla, June. Work of this nature was very common on other species of composites particularly in the Valley of Mexico in October.

Snout beetle—One adult of ***Rhodobaenus***—gnawing into tip of Pamakani and causing it to wilt—Cuernavaca, October. This beetle very common and causing such injury to *Montonoa* sp. Valley of Mexico, October.

A gall insect—Hymenopter in mid rib and petioles of leaves.

Of the insects attacking the stalk, the weevil and lepidopterous borer attacking the plant at the base, by the nature of their work, are capable of very seriously

affecting Pamakani, if abundant, as is also the case with the weevil grub in the tip, though this latter I believe is common to other composite plants. The Trypetid stem gall is widespread, in spite of severe parasitism. It might be of some value in checking the vigor of Pamakani in Hawaii where free from parasites, and should be fairly easy to handle. I have not observed it on other plants.

Sucking insects: stem and leaf.

Cercopid—Cuernavaca, Oct., Nov.; Tepic, Nov.; Cuautla, June, larvae, adults, Nov.

Membracid—several species, one ovipositing in Pamakani, Cuernavaca, Oct.

Fulgorids—several species, collected only, Oct., Nov.

Jassids—half dozen species of which several are attached to Pamakani, Oct., Nov.

Orthezia—Cuernavaca, Cuautla, San Marcos, Tepic. Very noticeably injurious to individual plants at Cuernavaca in Oct. and Nov. This is similar in appearance to the *Orthezia* in Hawaii, though I have not seen it on lantana here. An *Orthezia* is quite common on garden ornamentals in Vera Cruz. At Cuernavaca, the *Orthezia* on Pamakani is attacked by a species of *Hyperaspis*.

Scale—Cuernavaca, Oct., April, observed on dead plants, perhaps old growth and on growing plants. Not on thrifty plants.

Aphids—several species, Oct., Nov., Cuernavaca.

Tingitid—collected, Cuernavaca.

White fly—all stages, Cuernavaca, Oct., April; Tepic, Nov.

It is particularly hard to estimate the drain on the plants by these insects, though the great potential capacity for injury which they possess is well known. I have not observed them in numbers on Pamakani, the cercopid, *Orthezia* and scale being limited to a very small percentage of the plants. One or more of the jassids and aphids are quite likely associated with diseased conditions observed in Pamakani, but to prove it definitely would be a project in itself. While potentially capable of exerting a very great check on Pamakani in Hawaii, I doubt if it will be considered advisable to introduce any one of them. Certainly not without much more information concerning them being available.

Leaf-miners, rollers, webbers.

Labyrinth mines—Mines of this type have been observed in all of the localities studied. The mines usually are in the lower leaves of the plant or in shaded places. There are possibly several species of insects forming these mines. In a large number kept for rearing a few moths were secured but more parasites. In one locality in Cuernavaca in April many plants had practically all leaves mined. Usually present elsewhere but not collected at Tepic.

Patch mines—There are several types of mines of this nature. One is caused by an agromyzid fly while another is made by a moth. These are widely spread over the Pamakani territory but appear to be so well controlled by parasites that only a comparatively small number have been collected. The nature of their work on the leaf is more serious than the labyrinth miners appear to be.

Spot mines—A leaf miner which spins a cocoon between the leaf surfaces making a distinct white spot on the leaf—the adult is a moth or a close relative. This is very common on *Montonoa* and related plants, in the Valley of Mexico and on related plants about Cuernavaca but only a few have been collected on Pamakani.

Leaf roller—Not reared, Cuernavaca.

Lepidopter—folding over edge of leaf—a few Cuernavaca—parasitized.

Terminal tip and leaf webber—This is a small green caterpillar a dozen of which were brought in for rearing at Cuernavaca, Nov., but not completed to adult at the time I left. It has been observed occasionally in other localities. Several were parasitized.

Leaf cutter and twister—About a dozen specimens half grown or more of this caterpillar were collected at Cuernavaca in November. Four or five species of parasites were secured but no adults of the caterpillar. It was observed at San Marcos, Jalisco and Tepic as well. It makes a very noticeable whorl of the cut leaf. I have not noticed it on other plants, than Pamakani.

The leaf-miners, rollers, and webbers appear to me to be well worth more extended investigation.

At San Marcos and at Tepic, a small caterpillar scraping the surface of the Pamakani was observed.

In all some dozen of caterpillars have been collected feeding externally upon the Pamakani in addition to the species more specifically attached to it. Only a few individuals of each, however, were observed and these mostly at Cuernavaca in October and November. A species of bag worm was collected at Cuernavaca in April. Shortly before leaving Cuernavaca in November a species of webworm appeared. Some half dozen plants were observed with the terminal leaves webbed together by a mass of small caterpillars. A species of *Apion* has also been collected on the leaves.

The leaves are also eaten to some extent by such indiscriminate insects as grasshoppers, several species being collected.

Insects attacking the flowers.

Cecidomyid—common late in April—Cuernavaca.

Trypetid—Cuernavaca, April.

Tortricid—one specimen—Cuernavaca, April.

Snout beetles—Several species were collected in flower heads—Cuernavaca—in April—injury not definite. Common.

Thrips—Several species, Cuernavaca, April. Injury if any not definite.

Capsid—Nymphs and adults, Cuernavaca, April.

The trypetid, cecidomyid and tortricid are definitely injurious in their attack on Pamakani, but the last named was so rare in April as to be almost non-existent so far as importance to Pamakani is concerned.

The trypetid appeared in very small numbers early in April, hundreds of flower heads examined in most situations showing only a few individuals of the fly. One small lot, however, of 350 flower heads showed 30 attacked and another of 150 heads showed 25 attacked. By the last week in April, the trypetid had become more widespread and was found in all of the situations examined. A count of several thousand heads indicated an average percentage infestation of somewhat under 10 per cent. Since a flower head infested by a single trypetid still produces at least half the normal number of seeds, the percentage is still further reduced and when it is considered that it is only late in the season that even this percentage is reached it is seen that the effect of the fly for a season is reduced to a very negligible figure. An actual count indicated an average reduction of the seeds in an infested head of nearly half but this was in a situation also affected by the cecidomyid. An infested head examined at an early stage shows the partly grown maggots surrounded by a cluster of shrunken seeds. The seeds at this time that are not affected are just beginning to harden and color. The fly develops and pupates in the flower head, the puparium being embedded

endwise into the receptable where it remains surrounded by a ring of seeds after the healthy seeds have matured and dispersed. The same, or a very similar, trypetid was reared from a related plant at Cuernavaca in September, and in large numbers at Oaxaca in September as well as at Orizaba.

The cecidomyid larvae were observed in Pamakani flowers at Cuernavaca in early April, but had increased very noticeably 3 weeks later. Where only a few individuals are present in a flower very little injury is apparent. They do cause a shrinking of the seeds in the earlier stages and later when 10, 12 or even as in one case 17 are counted in a single head, the effect is quite noticeable. In the case where 17 were in one head not a single sound seed developed. One lot of 50 heads showed 42 infested with 115 cecidomyids, 10 trypetids, 29 hymenopters. To express the damage by this fly on a percentage basis would be rather more difficult than by the trypetid, it does, however, appear to be of greater importance at Cuernavaca than the trypetid. Similar cecidomyids are common in October on related flowers in the Valley of Mexico.

Tortricid.—Hardly less than 10,000 flower heads were examined in the two trips to Cuernavaca. Just one larva of a tortricid moth, since reared, was obtained. It eats out the developing seeds. The same or a very similar species was found in a related plant flower at Cuernavaca and Oaxaca in October.

Parasites.—A half dozen different species of Hymenoptera were reared out of the Pamakani flower heads. One is a parasite that issued from the pupal stage of the trypetid. Parasite larvae have been observed externally on the cecidomyid larvae and also hyperparasites. One may possibly attack the flower.

Under the conditions at Cuernavaca, the Pamakani plants produce an enormous surplus of seeds so that the very small percentage injured toward the end of the season would hardly seem to be an important factor. If transplanted to Hawaii, the insects would be freed from parasitism but would on the other hand have to breed up during a very short flowering season and would have to survive a long season without alternate plants. All of the insects here mentioned in the flowers also occur as well in related flowers in the late summer and fall at Cuernavaca.

Plant Diseases. Two diseases appearing on Pamakani are here mentioned as noticed at Cuernavaca in October, but it is by no means intended to imply that diseases do not occur. A pathologist would no doubt find a number of fungi and bacteria to attack the plant. No widespread or pronounced disease conditions were noticed, however.

In October, a number of clumps of Pamakani had a "curly leaf" condition similar to the "curly leaf" of sugar beets in appearance and quite possibly likewise associated with one of the species of jassids. The size of the plants did not seem noticeably affected and I am not able to say whether the condition prevents flowering, as it had entirely disappeared in the spring as had the jassids also. Specimens of the diseased plants were sent to Honolulu.

Plants. Under the conditions observed in Mexico, Pamakani does not appear to successfully extend itself against other vegetation. While able to grow in association with other plants to a certain extent, the tendency would seem to be for Pamakani to be crowded out except in situations unfavorable for other plants.

A few plants have been observed on stream banks where there is some grass but never out in open pasture or range. Lower down where ditches are overrun by grasses, Pamakani appears unable to get a foothold. In one place in Cuautla, a cut under the railroad is made in the middle of an irrigated field. This field is continually moist and the beans and corn planted there at present are almost swamped with cosmopolitan weeds and grass. Clinging to the dripping walls of the cut were flowering plants of the Pamakani. At the top and in the field only a few feet away not a single Pamakani plant could be found.

Thus, while in a general way it can be said that Pamakani is to a certain extent repressed by other plants, at the present time I am not able to point out any one plant which I could definitely say represses Pamakani here, is suitable or safe for introduction to Hawaii, and which at the same time could be predicted as likely to suppress or aid in suppressing Pamakani under the conditions in Hawaii.

IV. Control in Mexico

That the Pamakani is under great restraint in Mexico, as compared to Hawaii, is evident. The relative value of the different factors involved in this control is perhaps not so evident. One very important point, however, in explaining this control in Mexico, it seems to me, is the nature of growth of the plant together with the climatic conditions, a combination which tends to restrain Pamakani to within very limited habitats.

The Pamakani plant is of relatively slow growth and flowers only in spring at the end of the dry season. At the end of the short rainy season the plants are immature or at least do not produce flowers. Any plants not in protected situations or situations which hold a certain amount of moisture dry up before being able to produce flowers. While the plants in favored situations produce large numbers of seeds, this production is limited to a very small area. New growth is starting up beneath the old clumps in wet places.

It is quite probable that the seeds are scattered over the dry sections and at the end of the rainy season a few places not permanently moist had plants. However, they either do not germinate, or fail to compete if they extend to grass lands or sections already occupied by fast-growing weeds. I have not found any plants coming up in such situations yet this present rainy season. (I am planting some seeds in various situations for observation.) The seeds must also be carried to the irrigated and cultivated fields. That a plant of this character would not even get started is not so plain. Either the conditions for germination are not suitable or they are crowded out at the start in fallowed fields by the mass of weeds and grasses which spring up almost at once.

In the rainier districts such as Orizaba, the plant may be limited to a relatively greater extent by competition with other vegetation.

It has not seemed to me that the control of Pamakani in Mexico has been due to any great extent to the insects and diseases that have been noticed. Still, as I have not seen the plant growing where free from attack, I may possibly underestimate the effect of a retarded growth in the competition with other plants. While a large number of insects have been mentioned and the work of some of

them definitely noted as injurious in character, still the actual abundance of the insects has hardly seemed large enough to be of any great importance. A larger number occur in the more open situations. In favorable situations the Pamakani plants mature and produce seed in spite of the insects. Of one thing, though, I feel quite certain, this past season the seed-infesting insects were of no importance in suppressing Pamakani.

V. Possibilities of Control in Hawaii

First—By the introduction of parasites along the line used in the control of the Lantana in Hawaii.

While not perhaps of prime importance in Mexico, being themselves held in control, it is reasonable to expect that any insect introduced into Hawaii would increase to a great extent; such was the case in the introduction of the lantana insects. If only those insects already noted (and the list is by no means complete) were introduced into Hawaii I feel quite sure that the Pamakani would be very greatly reduced on the ranches. I doubt if the Pamakani would be very seriously affected in such situations as the Iao Valley and I do not know that it is desired to do so. Unfortunately, some of perhaps most value against Pamakani are not considered suitable for introduction.

The various leaf-feeding caterpillars, by defoliating the plant would at the same time give the grass a better chance to grow and make condition for new growth of Pamakani unsuitable. The sucking insects mentioned would greatly stunt the plants. Until the food plant range of each of these insects is much better known, however, it would not be advisable to consider their introduction.

The following general list of insects is perhaps more specifically attached to Pamakani and is suggested for further consideration: the stem and tip borers, leaf-miners, gall insects, the leaf-cutters and rollers and the tip webbers. Each of these is definitely injurious to the plant and a combination of them if able to multiply unchecked ought to be of value in Hawaii, though they could hardly be expected to so completely suppress the plant as the first two groups (defoliators and sucking insects) mentioned.

The flower insects are perhaps worth trying, though the ability to bridge over the long season without flowers is doubtful.

The insects referred to as the trypetid stem gall and the leaf-cutter and twister are distinctive in their work and have not been noticed on other plants, and their introduction to Hawaii would seem to be reasonably safe. The trypetid in the flower heads is also probably safe for introduction. The shipment of the two trypetids would be quite a simple matter.

In considering the introduction of insects to control a pest of importance to only a part of the Territory, the risks should be particularly emphasized. I feel that there is little danger that the insects mentioned would attack the main crops of Hawaii: sugar cane, pineapples and bananas. It is very hard to say, however, that they would not attack such plants as some of the garden ornamentals, or forest shrubs. It is for this reason that I think the insects should be more extensively studied before any introductions.

Second—By suppressing it with hardy plants which would have value as forage.

While it seems true that in Mexico the competition with other plants is perhaps of greater importance than the attack by insects, this appears to be due at least in part to conditions that would not hold in Hawaii, and to a large extent to plants not suitable for introduction. I take it that plants acceptable for introduction on the range would be limited pretty closely to species of grass. Some of the species of grass native to Mexico might be suitable for the ranges in Hawaii. It is a question that I would not feel qualified to decide. That they could be introduced without any assurance that they would spread and crowd out Pamakani seems to me to be very doubtful. The introduction, trial and experimentation with plants of known forage value with the idea of improving range conditions is, I believe, already being done. Some of these may prove of value against Pamakani. I doubt if anything more would be accomplished by seeking for a plant specifically to suppress Pamakani.

In conclusion, it would seem to me that of the two suggestions made for the control of Pamakani, the first offers the more definite chance for success; that if the Pamakani plants are stunted by insects, which seems very feasible, the grasses already occurring there will be grown more vigorously, producing a condition under which Pamakani would tend to be suppressed. A rather slight checking of Pamakani might be sufficient to bring this about.

In case it is decided to continue the investigation of Pamakani with an idea of controlling it by insect introductions, I would recommend that at least three months be spent continuously in some such locality as Cuernavaca, Morelos, the time to be devoted to the study of the insects already observed and any others that might appear, especially as to their range of food plants. From the middle of August until the middle of November would be a suitable time.

It would not be necessary to remain there during the winter months and might be advisable to investigate the Pamakani at that time in Central America.

I would prefer to postpone any shipments of insects to Hawaii until they have been more continuously studied.

(From a letter received from Mr. Osborn dated July 6, 1924.)

The following localities may be added to the list for Pamakani. The mountain sopes above Cuautla, Morelos. The highest point definitely noticed was where occasional clumps occurred in the railroad cuts between Nepantla and Tlacotitlan in the state of Mexico at 6,800 feet. They no doubt occur in favorable and sheltered spots on this the south slope of the mountains to somewhat higher elevations in this locality.

There are a number of rather favorable Pamakani situations not previously noticed near Cuautla but I still consider Cuernavaca as offering the better opportunities for study. The higher elevations can be reached just as conveniently from there.

In reading over the Pamakani report there is one point concerning the plant growth that I perhaps did not make quite clear. At the end of the rainy season last year, plants plainly seedlings from several inches to a couple of feet in height

were collected and included in the plant specimens sent to you. The larger clumps, however, appeared to be of more than a year's growth, perhaps several. At this time of year in very favorable spots I find a very few small seedlings which I take to be Pamakani. The bulk of the new growth though is the shoots from the base of the old clumps and branches from the stems. At the end of the flowering season the tips bearing the flower clusters wilt back but the main stalk does not die, though eventually the old stems would tend to be crowded out by the new branches and shoots.

You may perhaps have some information as to how long the plants persist in Hawaii.

In making recommendations these points were considered. In fact that is one of the reasons why the seed insects appeared to me to be of so little importance here in Mexico.

I found one plant yesterday with a flower cluster of a dozen heads. A very rare occurrence at this time of year. A few of the insects not noticed since last fall are showing up again.

Clarification

Characteristics of Clarified Juice at High Temperatures

By H. F. Bomonti and W. R. McAllep

This investigation was undertaken to obtain information on the changes in hot clarified juices, and to define, if possible, what, from the standpoint of raw cane sugar manufacture, may be termed a neutral point or zone. This may be defined as a reaction or range of reactions under which sucrose is not inverted and glucose is not destroyed, or if these changes take place at all, they proceed slowly enough so that their effect is negligible. Micro-organisms can develop and destroy both sucrose and glucose under any conditions of acidity or alkalinity practicable in raw cane sugar manufacture. Previous work in this laboratory has defined the upper limit of bacterial growth in juices as 160° to 165° F. In the absence of germicides, losses of glucose and sucrose are probable, below this temperature. Consequently this investigation has been confined to temperatures above 165° F.

Definite information on destruction of sugar and the conditions governing it, at temperatures above where bacterial action is a factor, is necessary if losses are to be reduced to a minimum and factory operations carried on efficiently. Similar information on destruction of glucose is also important, though loss of glucose is less serious than loss of sucrose.

In the beet sugar industry, information satisfactory from an operating standpoint has long been available. Here the problem is comparatively simple. Glucose is purposely destroyed in one of the first steps of the process. With the glucose originally present destroyed, a qualitative test showing the presence of glucose is

sufficient to detect even very small losses of sucrose through inversion. With the danger point thus easily located, but little uncertainty exists as to the reaction at which a material amount of inversion will be encountered. Further, in the absence of glucose, there is no objection to operating at a moderate alkalinity. The juices are usually maintained sufficiently alkaline so there is a good margin of safety and material losses through inversion in beet sugar factories are rare.

In a cane sugar factory detecting inversion of sucrose is more complicated. The glucose content of the entering juice is constantly changing and further changes in the glucose content take place during clarification. Under such conditions instead of a simple qualitative test being adequate, the most accurate control and analytical methods are necessary to detect even material amounts of inversion. Instead of adequate information as in the beet sugar industry, in the cane sugar industry many conflicting theories have been given credence, resulting in much confusion and great diversity of opinion.

A large amount of scientific research has been devoted to sucrose and the reducing sugars commonly classed as glucose in the sugar industry. Hydrolysis or inversion of sucrose, for instance, has probably been studied as much as any single chemical reaction. After so much work it would seem that there should be little uncertainty as to the conditions governing it. By far the greater part of this work however, is not particularly relevant to the question of what is a safe reaction for juices in factory practice, for it has been measurement of the speed of inversion at comparatively high velocities. Other work at lower velocities bears a closer relation to the question, but even this has been done in solutions that in comparison with highly complex solutions such as cane juice, may be termed "pure solutions." Comparisons of reactions in a simple solution with reactions in a complex solution on the basis of total acidity or alkalinity determined by titration are of little value. This is the only basis that has been available in factory practice. If hydrogen ion concentration measurements, instead of titration figures had been available, inversion of sucrose in juices might have been properly correlated with data for inversion of sucrose in pure solutions. Under existing conditions, however, strictly scientific research has not defined for the factory operator, the point where juices may be carried without danger of inversion. For quite similar reasons strictly scientific research has not defined the conditions attendant on the destruction of glucose in such a manner that the information has been directly applicable to sugar factory practice.

Confusion and diversity of opinion, however, are largely the result of observations and investigations on cane juice itself. This is not at all surprising when we consider the loose way in which the terms "acidity," "alkalinity" and "neutrality" have been used, the comparatively large factor of error in methods of sugar analysis and other difficulties attendant on investigation of juices.

The loose way in which "acidity," "alkalinity" and "neutrality" have been used is undoubtedly one of the principal reasons for the existing confusion. Litmus is commonly used for controlling factory operation, while laboratory investigations have usually been on the basis of phenolphthalein titrations. Due weight has not as a rule been given to the difference between these two indicators in translating laboratory investigations and data appearing in the literature to

factory practice. When titrating strong acids such as hydrochloric acid with a strong base such as sodium hydroxide, the difference in end point between litmus and phenolphthalein is very small, almost negligible. In complex solutions such as cane juices, substances termed buffers are present, and due to their influence, titration results show a material difference between the two end points. Actually the range of reactions at which it is practicable to carry juices in a raw cane sugar factory is included between the points commonly termed "neutrality to litmus" and "neutrality to phenolphthalein." Neither coincide with the modern conception of true neutrality. The neutral or end points of litmus and phenolphthalein are at fairly definite hydrogen ion concentrations and thus are in relation to each other, but values obtained by titrating juices with one indicator are not in any definite relation to similar values obtained with the other. Neither can they be translated into terms of hydrogen ion concentration.

Reasonably satisfactory methods for determining hydrogen ion concentration have been generally available for only some ten years, except in scientific institutions. It is only in the last three or four years that such measurements appear to have been applied to the investigation of sugar factory problems. Had hydrogen ion concentration measurements been made in connection with earlier work, much of the confusion attributable to the manner in which acidity, alkalinity and neutrality have been used, would doubtless have been avoided.

Also, in investigations on juices but little attention has been given to a most significant factor: the development of acidity in juices on standing. This renders investigation of changes in juices a most complicated problem. Failure to give it due consideration has undoubtedly led to erroneous conclusions.

The comparatively large factor of error in methods of sugar analysis, previously mentioned, would not be a serious difficulty if a supply of raw material of the same composition were available from time to time. In an investigation on sugar for instance, portions of an original sample may be kept for weeks without alteration. A series of experiments can be made under the same conditions, and the analyses averaged. These averages will reduce the effect of errors in individual determinations and show what actually happened during the experiments with a satisfactory degree of accuracy, even though factors of error in the analytical methods employed are rather large.

With juices the samples begin to alter almost immediately. Also it is hardly probable that any two samples are of exactly the same composition. Differences in the original samples are further accentuated by differences in behavior on clarification and unavoidable difference in clarification procedure, for it is most difficult to exactly duplicate clarification procedure from time to time. This prevents making a series of experiments under exactly the same conditions, and the number of analyses is limited to those that can be made before the samples alter. Reducing the factor of error by averaging analyses is thus of limited application. By grouping experiments made under close to the same conditions changes during the experiments may be averaged, but to secure valid averages in this way a large amount of data must be available. There is little doubt but that changes sufficiently large to be significant from a manufacturing standpoint have not been detected in investigations on juices because of the comparatively large factor

of error in analytical methods and difficulties in securing closer results through averaging analyses.

In taking up this investigation, one of two courses had to be chosen, either planning the work to obtain a broad general view of what takes place in a clarified juice at high temperatures, or taking up a single phase at a time and studying it in greater detail. Little or no definite information on the changes that take place was available, so it was necessary to adopt the former plan. This investigation therefore is extensive rather than intensive; that is, each sample of juice has been studied at as many different reactions and as many different factors have been determined as the work that could be done before the samples altered would permit, thus providing the necessary foundation for future work in which the work that can be done before the samples alter may be concentrated on more closely defining details. The procedure adopted was to clarify portions of a sample of juice with varying amounts of lime and digest the resulting clarification series for 22 hours, comparing the analyses before and after digestion. It was found that the desired determinations could be made on a clarification series of five members. A comparatively long digestion time was chosen to accentuate changes and to obtain information directly applicable, in factory practice, to the problem of preserving juices over night and during shut-downs.

The procedure in detail was as follows: Juice for most of the experiments was obtained by grinding cane in a small three-roller mill, the bagasse being again passed through once or twice, after sprinkling with water, so the juice would more nearly approximate ordinary mixed juice. Some three-quarters of the samples were from cane grown at the Makiki plots. Clarification procedure in most of the experiments was similar to that used in studying increases in purity. Five portions of juice were limed to different reactions in the presence of the cush cush the juice happened to contain, brought to the boiling point, filtered with kieselguhr, and analyzed. About one liter of each portion was placed in a tightly stoppered copper container, brought to the desired temperature, digested at this temperature in an electric oven for 22 hours and analyzed. The analyses included brix, polarization, sucrose, glucose, titration with phenolphthalein, titration with litmus, and hydrogen ion concentration.

Analytical Methods

Brix was usually determined with a hydrometer. The readings were estimated to the nearest hundredth, though .03 to .04 was about as close as they could be made with certainty. In several of the experiments brix was determined with a pycnometer, in which analyses the probable error does not exceed .01 to .02.

Polarization was determined by Horne's dry lead subacetate method.

Sucrose was determined by the Hawaiian Chemists' Association method, using the Walker method of inversion. During the course of this work the sucrose determinations, before and after digestion, were checked with chemical sucrose determinations, to see if the digestion affected the relative results. It was found that any possible changes were too small to be thus detected, and in any case, were small enough to be considered negligible.*

* Record, Vol. XXVII, p. 145.

The factor of error in purities as calculated from these determinations is rather large, a total error of 0.1, which it will be noted may be the sum of the errors in four determinations, two each of brix, and sucrose or polarization, corresponding to approximately 0.7 in purity.

Glucose was determined by the Munson and Walker method. Sufficiently consistent results were not secured by weighing the reduced copper as cupric oxide, so after the first experiment, reduced copper was determined by the thiosulphate method, details of which are in the article referred to above. With careful attention to details and determining the reduced copper in this way, entirely satisfactory results were secured. The maximum probable error in these determinations is about 0.01 per cent and it is improbable that the maximum error in a comparison involving two determinations exceeds 0.02 per cent.

Reaction to phenolphthalein was determined by titrating ten c.c. of juice diluted to 100 c.c. with distilled water, with N/28 sodium hydroxide or sulphuric acid. The end point was not particularly sharp in dark colored juices.

Reaction to litmus was determined by adding N/28 alkali or acid in small portions to undiluted juice, until the end point was passed. After each addition, a drop of the juice was placed on a strip of non-absorbent, sensitive litmus paper. After the last addition the drops were shaken off, leaving a row of spots, graduated in color from pink to blue. The end point can be determined with a high degree of accuracy even when titrating very dark juices. Reaction to both litmus and phenolphthalein are expressed as per cent CaO.

Hydrogen ion concentration was determined with a Hildebrand type of hydrogen electrode and a one-tenth normal calomel cell. Figures for hydrogen ion concentration are unwieldy, so for convenience the results are expressed in pH values. The pH value is the logarithm of the reciprocal of the hydrogen ion concentration in grams per liter. Figures lower than seven indicate excess of hydrogen over hydroxyl ions or acidity. Figures higher than seven indicate hydroxyl in excess of hydrogen ions, or alkalinity. Seven is true neutrality, that is, exactly the same concentration of hydrogen and hydroxyl ions.* These determinations were made on samples diluted with three volumes of water to avoid some difficulties encountered when using the hydrogen electrode in undiluted juice. Later work indicates that this dilution may cause a slight increase in pH, between seven and eight, the pH range in which we are particularly interested. This varies from 0 to a maximum of 0.2, and pH values in these data may exceed the actual pH by such an amount.

Though analyses have not been made in duplicate, those for the same experiment are to some extent a check on each other. The clarified juices before digestion form a clarification series. Fairly well defined purity relations and also some information on relative glucose content in the juices in such a series have been developed by previous work. The analyses before digestion in each experiment have been made at the same time and under the same temperature conditions. Also the samples are of common origin. Direct polarization by the dry-lead method under such conditions is subject to a minimum of manipulative error and is of high relative accuracy, though its relation to true sucrose changes with varying amounts of glucose. If the latter is taken into consideration the value for sucrose minus polarization in a series such as we are considering may be used to detect irregularities in sucrose determinations, which are subject to more manipulative error than polarizations. The above is equally applicable to sucrose determinations in the juices after digestion. Unfortunately, there is less of a

* For further discussion of pH values, refer to the Record, Vol. XXVIII, p. 120, and Clark's Determination of Hydrogen Ion.

check on the accuracy of brix determinations, which on the whole are the least satisfactory of the determinations in these analyses. Evaporation during clarification causes irregular changes in density so the brix of juices after clarification are not necessarily in definite relation to each other. Comparisons of brix before and after digestion are of somewhat more value. Even in this case evaporation from imperfectly closed containers can cause an increase in brix during digestion. This happened in a number of instances. Inversion of sucrose also causes a very slight increase in brix. However, a decrease of over a few hundredths during digestion under the conditions of these experiments, can hardly be accounted for except by an error in reading the hydrometer. In three cases comparisons strongly indicate such an error approximating one-tenth degree. Analytical data secured in this investigation have been carefully examined as indicated above. Information so secured has been of great assistance in deciding on the weight to give individual purity determinations.

Experimental Data

The tables which follow contain condensed data for the different experiments and conclusions with respect to inversion. In arriving at conclusions, glucose determinations have been given greater weight than purities. An increase in glucose during digestion of over 0.02 has been accepted as "positive" evidence of inversion. Inversion has also been considered "positive" when an increase of 0.02 in glucose has been accompanied by decreases in purity and in the sucrose-glucose ratio. Inversion has been considered "probable" where an increase of 0.01 in glucose has been accompanied by decreases in purity and in the sucrose-glucose ratio. In a few instances juices have been designated as "doubtful" because of some indications of inversion which are hardly definite enough to justify the designation "probable."

Significant features of the experiments are pointed out in the comments accompanying the tables. Where the comparisons previously discussed have indicated probable analytical errors having any bearing on the conclusions, this is also noted.

The figures 1 to 5 in the following tabulations designate the clarified juices secured by clarifying the original sample with different amounts of lime, No. 1 being the most acid and No. 5 the most alkaline clarification. The relative amounts of lime are indicated immediately below, the figures referring to cubic centimeters of a lime suspension used per liter of juice. The first of the three columns for each member of the clarification series, designated "before," is the analysis of the clarified juice. The second, designated "after," is the same juice after digestion. Changes that have taken place during digestion are indicated in the third column. In this column dark-face indicates *minus*, and light-face figures *plus* differences. Acidity to phenolphthalein or litmus is in dark-face, while alkalinity is in light-face figures. Figures for reaction, in the third column, refer to changes in the direction alkaline to acid, there being no changes in the opposite direction. S/G is an abbreviation for the sucrose-glucose ratio and S—P is an abbreviation for sucrose minus polarization.

Experiment 1 at 180° F.: This first clarification series covers a wide range of reactions, 1 being neutral to litmus, or slightly on the acid side of true neutrality, 3 neutral to phenolphthalein, 4 and 5 alkaline to phenolphthalein. All of the juices changed in reaction towards acidity during digestion irrespective of whether the original reaction was alkaline or acid. There are increases in glucose of .02 or more accompanied by decreases in purities and sucrose-glucose ratios in 1 and 2. Inversion has been designated as positive. In 3 there is no change in glucose. There is a decrease in gravity purity but as the value for sucrose minus polarization is low in comparison with the other juices after digestion, indicating a slightly low sucrose determination, the purity decrease alone has not been considered sufficient evidence of inversion to class this juice as "doubtful." Juices 3, 4 and 5 have been designated as showing no inversion.

It will be noted that inversion has been detected in 2 at .005 alkalinity to litmus and 7.68 pH after digestion. Inversion has therefore taken place in a juice alkaline to true neutrality. It has not been detected, however, in the more alkaline juices, 3, 4 and 5. At .008 alkalinity to litmus and 8.18 pH is the lowest alkalinity at which inversion was not detected.

EXPERIMENT NO. 1 AT 180°.

	1			2			3			4			5		
	3 cc Lime			6 cc Lime			9 cc Lime			12 cc Lime			15 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	13.72	13.85	.13	13.64	13.66	.02	13.68	14.22	.54	13.85	13.83	**.02**	13.71	13.65	**.06**
Pol.	12.65	12.57	**.08**	12.65	12.65	**0**	12.74	13.23	.49	12.85	12 85	**0**	12.71	12.67	**.04**
Sucrose .	12.77	12.71	**.06**	12.77	12.76	**.01**	12.86	13.31	.45	12.92	12.94	.02	12.78	12.76	**.02**
Glucose .	.06	.24	.18	.06	.08	.02	.06	.06	**0**	.03	.03	0	.02	.02	0
Apt. Pty.	92.21	90.76	**1.45**	92.74	92.61	**.13**	93.13	93.04	**.09**	92.78	92.91	.13	92.71	92.82	.11
Gr. Pty..	93.08	91.77	**1.31**	93.62	93.41	**.21**	94 01	93.60	**.41**	93.29	93.56	.27	93.22	93.48	.26
S/G	213	53	**160**	213	160	**53**	214	222	8	431	431	0	639	638	**1**
S—P ...	.12	.14	.02	.12	.11	**.01**	.12	.03	**.04**	.07	.09	.02	.07	.09	.02
Phenol ..	**.014**	**.020**	.006	**.007**	**.009**	.002	0	**.004**	.004	.001	**.002**	.003	.006	.004	.002
Litmus ..	0	**.006**	.006	.008	.005	.003	.012	.008	.004	.014	.010	.004	.020	.016	.004
pH	6.86	6.58	.28	8.10	7.68	.42	8.80	8.18	:62	9.11	8.44	.67	9.96	9.47	.49
Inversion		Positive			Positive			None			None			None	

Experiment 2 at 180° F.: Experiment 2 does not cover as wide a range of reactions as Experiment 1, nor is it so alkaline, 1 being slightly acid to litmus, 5 slightly alkaline to phenolphthalein and the other three juices between the neutral points of these indicators. The containers were not closed during this experiment and juice temperatures were probably somewhat below 180° F. because of the cooling effect of evaporation in open containers.

Reactions again change toward acidity during digestion. Juices 1, 2 and 3 show increases of over 0.02 in glucose and decreases in sucrose-glucose ratios. There are also decreases in purities except in 3. Inversion has been designated as positive in all three, comparisons of sucrose minus polarization indicating that the increase of 0.24 in gravity purity in 3 is due to a slightly high sucrose determination in the analysis after inversion. The increase of 0.01 in glucose in 4 corresponds approximately to the increase in density during digestion. In 5 also a similar increase in glucose is partially accounted for by an increase in density. Juices 4 and 5 have been designated as showing no inversion.

EXPERIMENT NO. 2 AT 180°.

	1 — 2.5 cc Lime			2 — 5 cc Lime			3 — 7.5 cc Lime			4 — 10 cc Lime			5 — 12.5 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	14.01	13.97	.04	13.75	13.82	.07	13.60	13.62	.02	13.71	14.00	.29	13.64	13.77	.13
Pol.	11.65	11.18	**.47**	11.63	11.57	**.06**	11.57	11.55	**.02**	11.77	12.00	.23	11.76	11.87	.11
Sucrose .	11.80	11.48	**.32**	11.80	11.75	**.05**	11.71	11.76	.05	11.84	12.12	.28	11.87	11.99	.12
Glucose .	.68	1.08	.40	.67	.76	.09	.64	.68	.04	.63	.64	.01	.59	.60	.01
Apt. Pty.	83.16	80.03	**3.13**	84.58	83.72	**.86**	85.10	84.80	**.30**	85.85	85.71	**.14**	86.22	86.20	.02
Gr. Pty..	84.22	82.20	**2.02**	85.82	85.02	**.80**	86.10	86.34	.24	86.36	86.57	.21	87.02	87.07	.05
S/G	17.35	10.63	**6.72**	17.61	15.46	**2.15**	18.30	17.29	**1.01**	18.79	18.94	.15	20.12	20.00	.12
S—P ...	.15	.30	.15	.17	.18	.01	.14	.21	.07	.07	.12	.05	.11	.12	.01
Phenol ..	**.042**	**.051**	.009	**.032**	**.031**	.001	**.016**	**.016**	0	**.002**	**.012**	.010	.002	**.008**	.010
Litmus ..	**.004**	**.008**	.004	.003	**.002**	.005	.008	.003	.005	.011	.005	.006	.014	.012	.002
pH	6.24	5.99	.25	6.78	6.41	.37	8.18	6.86	1.32	8.55	7.25	1.30	8.69	7.34	1.35
Inversion		Positive			Positive			Positive			None			None	

Experiment 3 at 180° F.: The cane in Experiment 3 was allowed to lie on the ground for three days after cutting. The clarified juices were slightly less alkaline than corresponding juices in Experiment 2. All juices changed in reaction towards acidity. Inversion is positively indicated in juices 1, 2, 3 and 4 by increase of over 0.02 in glucose accompanied by decreases in purities and in sucrose-glucose ratio. Inversion has been designated as "probable" in 5. The least alkaline juice in which inversion was positively detected, 4, was .010 alkaline to litmus and 7.25 pH, with probable inversion in 5 at .012 alkalinity to litmus and 7.51 pH.

EXPERIMENT NO. 3 AT 180°.

	1 — 2.5 cc Lime			2 — 5 cc Lime			3 — 7.5 cc Lime			4 — 10 cc Lime			5 — 12.5 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	15.47	15.45	.02	15.42	15.40	.02	15.42	15.43	.01	15.33	15.32	.01	15.43	15.42	.01
Pol.	13.10	12.70	.40	13.19	12.89	.30	13.25	13.21	.04	13.21	13.17	.04	13.37	13.36	.01
Sucrose .	13.32	13.04	.28	13.39	13.17	.22	13.44	13.39	.05	13.42	13.37	.05	13.58	13.54	.04
Glucose .	.60	.91	.31	.59	.81	.22	.58	.63	.05	.56	.60	.04	.51	.52	.01
Apt. Pty.	84.68	82.20	2.48	85.54	83.70	1.84	85.93	85.61	.32	86.17	85.97	.20	86.65	86.64	.01
Gr. Pty..	86.10	84.40	1.70	86.84	85.52	1.32	87.16	86.78	.38	87.54	87.27	.27	88.01	87.81	.20
S/G	22.20	14.33	7.87	22.70	16.26	6.44	23.17	21.25	1.92	23.96	22.28	1.68	26.63	26.04	.59
S—P ...	.22	.34	.12	.20	.28	.08	.19	.18	.01	.21	.20	.01	.21	.18	.03
Phenol ..	.042	.045	.003	.028	.036	.008	.015	.022	.007	.006	.014	.008	.000	.008	.008
Litmus ..	.006	.008	.002	.002	.001	.003	.006	.006	0	.014	.010	.004	.018	.012	.006
pH	5.98	5.90	.08	6.61	6.32	.29	7.51	6.91	.60	8.27	7.25	1.02	8.64	7.51	1.13
Inversion		Positive			Positive			Positive			Positive			Probable	

Experiment 4 at 180° F.: The cane in Experiment 4 was part of the sample used in Experiment 3, ten days after cutting. In this time the cane had deteriorated, the purities being much lower and glucose much higher than in the preceding experiment. With approximately the same amounts of lime used, juices 1, 2 and 3 are considerably less alkaline than corresponding juices in Experiment 3. Juices 4 and 5 are also less alkaline to phenolphthalein but are close to the same litmus reactions and pH values as corresponding juices in the preceding experiment. Deterioration appears to have made considerable changes in the relative values of litmus titration, phenolphthalein titration and pH.

Juices 1, 2, and 3 show positive inversion. Juice 4 has been classed as "doubtful" on account of moderate decreases in purities though no increase in glucose is indicated. Number 5 shows no evidence of inversion; on the contrary, there is a decrease of 0.02 in glucose. This is the only instance in these experiments where a fairly definite indication of destruction of glucose during digestion is found. The least alkaline reaction at which inversion is positively shown is .002 acidity to litmus and 6.15 pH with possible inversion at .004 alkalinity

to litmus and 7.22 pH, while the least alkaline reaction showing no inversion is .010 alkalinity to litmus and 7.59 pH.

EXPERIMENT NO. 4 AT 180°.

	1 — 2.5 cc Lime			2 — 5 cc Lime			3 — 7.5 cc Lime			4 — 10 cc Lime			5 — 12.5 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	14.90	14.92	.02	14.93	14.94	.01	14.79	14.77	.02	14.64	14.66	.02	14.72	14.72	0
Pol.	9.70	8.95	.75	9.91	9.33	.58	9.85	9.64	.21	9.80	9.75	.05	9.85	9.86	.01
Sucrose	10.17	9.60	.57	10.36	9.94	.42	10.27	10.14	.13	10.20	10.15	.05	10.28	10.28	0
Glucose	2.64	3.29	.65	2.63	3.05	.42	2.60	2.74	.14	2.58	2.58	0	2.55	2.53	.02
Apt. Pty	65.10	59.99	5.11	66.38	62.45	3.93	66.60	65.27	1.33	66.94	66.51	.43	66.92	66.98	.06
Gr. Pty	68.26	64.34	3.92	69.39	66.53	2.86	69.44	68.65	.79	69.67	69.24	.43	69.84	69.84	0
S/G	3.85	2.92	.93	3.94	3.26	.68	3.95	3.70	.25	3.95	3.93	.02	4.03	4.06	.03
S—P	.47	.65	.18	.45	.61	.16	.42	.50	.08	.40	.40	0	.43	.42	.01
Phenol	.063	.067	.004	.044	.050	.006	.028	.035	.007	.012	.025	.013	.004	.016	.012
Litmus	.010	.014	.004	.002	.007	.005	.002	.002	.004	.012	.004	.008	.018	.010	.008
pH	5.90	5.73	.17	6.15	5.99	.16	6.49	6.15	.34	8.25	7.22	1.03	8.60	7.59	1.01
Inversion		Positive			Positive			Positive			Doubtful			None	

Experiment 5 at 180° F.: Experiment 5 is a more alkaline series, all of the initial juices being alkaline to litmus and three alkaline to phenolphthalein. Inversion is positively indicated in 1 by an increase of 0.04 in glucose and decreases in purities and the sucrose-glucose ratio. Inversion has been designated as "doubtful" in 2 and 3 on account of small increases in glucose and decreases in sucrose-glucose ratios. Figures for juice 3 show increases in apparent and gravity purity during digestion. Comparisons do not indicate irregularities in polarization or sucrose determinations but do indicate a decrease in brix during digestion. This, as previously noted, is hardly to be accounted for except by an error in the brix determination. Initial purities are normal in comparison with initial purities in 2 and 4 locating the error in the analysis after digestion. Increases in purity in 3 are undoubtedly due to a minus error of approximately .1 in determining brix after digestion.

No increase in glucose or other evidence of inversion is shown by the analysis of juices 4 and 5.

The least alkaline reaction at which inversion was positively shown was .002 alkalinity to litmus and 7.25 pH, while the least alkaline juice showing no evidence of inversion was .007 alkaline to litmus and 8.01 pH.

EXPERIMENT NO. 5 AT 180°.

	1 — 10 cc Lime			2 — 12.5 cc Lime			3 — 15 cc Lime			4 — 17.5 cc Lime			5 — 20 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	15.68	15.67	.01	15.77	15.76	.01	14.60	14.50	.10	15.61	15.60	.01	15.30	15.30	0
Pol.	14.23	14.18	.05	14.32	14.31	.01	13.29	13.26	.03	14.18	14.16	.02	13.89	13.88	.01
Sucrose	14.40	14.34	.06	14.48	14.47	.01	13.40	13.39	.01	14.25	14.24	.01	13.96	13.96	0
Glucose	.55	.59	.04	.53	.54	.01	.39	.40	.01	.34	.34	0	.30	.30	0
Apt. Pty	90.75	90.49	.26	90.81	90.80	.01	91.03	91.45	.42	90.84	90.77	.07	90.78	90.72	.06
Gr. Pty	91.84	91.51	.33	91.82	91.82	0	91.78	92.35	.57	91.29	91.28	.01	91.24	91.24	0
S/G	26.18	24.31	1.87	27.32	26.80	.52	34.36	33.48	.88	41.91	41.88	.03	46.53	46.53	0
S—P	.17	.16	.01	.16	.16	0	.11	.13	.02	.07	.08	0	.07	.08	.01
Phenol	.006	.012	.006	.002	.010	.008	.001	.006	.007	.002	.004	.006	.003	.002	.005
Litmus	.008	.002	.006	.010	.004	.006	.012	.005	.007	.014	.007	.007	.016	.008	.008
pH	8.44	7.25	1.19	8.76	7.51	1.25	8.89	7.76	1.13	9.00	8.01	.99	9.09	8.10	.99
Inversion		Positive			Doubtful			Doubtful			None			None	

Experiment 6 at 180° F.: Experiment 6 is also a quite alkaline series. Reactions of the different juices are fairly close to those of corresponding juices in the preceding experiments. The analyses of 1 show an increase of .02 in glucose

and decreases in purities and sucrose-glucose ratios. Inversion has been designated as "positive." In 2 the analyses indicate an increase of 0.01 in glucose and a decrease in the sucrose-glucose ratio but increases in apparent and gravity purities. This is another instance where comparisons indicate a probable error of 0.1 in brix, in the analysis after digestion. This juice has been classed as "doubtful." In 3, 4 and 5 there are no increases in glucose or other indications of inversion.

In this experiment inversion has been positively detected at .006 alkalinity to litmus and 7.17 pH. The least alkaline juice in which there was no evidence of inversion was .010 alkaline to litmus and 7.34 pH.

EXPERIMENT NO. 6 AT 180°.

	1 — 10 cc Lime			2 — 12.5 cc Lime			3 — 15 cc Lime			4 — 17.5 cc Lime			5 — 20 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	14.37	14.38	.01	14.15	14.05	.10	14.37	14.36	.01	14.57	14.53	.04	14.27	14.25	.02
Pol.	13.05	13.03	.02	12.91	12.92	.01	13.22	13.22	0	13.30	13.30	0	13.04	13.05	.01
Sucrose	13.15	13.13	.02	12.98	12.98	0	13.29	13.28	.01	13.35	13.34	.01	13.09	13.09	0
Glucose	.22	.24	.02	.17	.18	.01	.16	.16	0	.08	.08	0	.07	.07	0
Apt. Pty	90.81	90.61	.20	91.24	91.96	.72	92.00	92.06	.06	91.28	91.54	.26	91.38	91.58	.20
Gr. Pty	91.51	91.31	.20	91.73	92.38	.65	92.48	92.48	0	91.63	91.81	.18	91.73	91.86	.13
S/G	59.77	54.71	5.06	76.35	72.11	4.24	83.06	83.00	.06	16.68	16.67	.01	18.70	18.70	0
S—P	.10	.10	0	.07	.06	.01	.07	.06	.01	.05	.04	.01	.05	.04	.01
Phenol	.004	.006	.002	.003	.004	.001	.001	.003	.002	.001	.003	.004	.002	.001	.003
Litmus	.008	.006	.002	.010	.008	.002	.014	.010	.004	.018	.010	.008	.020	.011	.009
pH	8.13	7.17	.96	8.44	7.25	1.19	8.52	7.34	1.18	8.86	7.88	.98	9.03	8.10	.93
Inversion	Positive			Doubtful			None			None			None		

Experiment 7 at 180° F.: Juices 1, 2 and 3 in Experiment 7 show positive evidence of inversion while no definite indications are apparent in juices 4 and 5. The pH values are not available in this experiment on account of trouble with the hydrogen electrode. Inversion is found up to .006 alkalinity to litmus while at .008 alkalinity or above inversion is not indicated.

EXPERIMENT NO. 7 AT 180°.

	1 — 12.5 cc Lime			2 — 15 cc Lime			3 — 17.5 cc Lime			4 — 20 cc Lime			5 — 22.5 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	15.85	16.12	.27	15.91	15.94	.03	15.63	15.72	.09	16.00	16.01	.01	16.05	16.07	.02
Pol.	13.32	13.21	.11	13.37	13.31	.06	13.18	13.05	.13	13.57	13.57	0	13.64	13.65	.01
Sucrose	13.62	13.62	0	13.65	13.59	.06	13.37	13.29	.08	13.75	13.73	.02	13.74	13.75	.01
Glucose	1.20	1.28	.08	1.16	1.24	.08	1.08	1.13	.05	1.01	1.01	0	.93	.93	0
Apt. Pty	84.04	82.00	2.04	84.04	83.50	.54	84.32	83.02	1.30	84.81	84.81	0	84.98	84.98	0
Gr. Pty	85.93	84.49	1.44	85.80	85.26	.54	85.54	84.54	1.00	85.94	85.76	.18	85.61	85.56	.05
S/G	11.35	10.64	.71	11.77	10.96	.81	12.38	11.76	.62	13.61	13.60	.01	14.77	14.78	.01
S—P	.30	.41	.11	.28	.28	0	.19	.24	.05	.18	.16	.02	.10	.10	0
Phenol	.005	.011	.006	.001	.011	.010	.000	.013	.013	.001	.010	.011	.002	.008	.010
Litmus	.008	.006	.002	.009	.006	.003	.009	.005	.004	.010	.008	.002	.012	.009	.003
pH	8.01	...	...	8.18	...	...	...	...	...	....	....	...	....	....	...
Inversion	Positive			Positive			Positive			None			None		

Experiment 8 at 180° F.: Experiment 8, the final experiment at 180° F., is a less alkaline series than the four preceding experiments. All the initial juices are between neutrality to litmus and neutrality to phenolphthalein. All show evidence of inversion. This experiment is less consistent than most of the others. However, evidence of inversion is shown up to the most alkaline juices in the series: .005 alkalinity to litmus and 7.42 pH.

EXPERIMENT NO. 8 AT 180°.

	1			2			3			4			5		
	5 cc Lime			7.5 cc Lime			10 cc Lime			12.5 cc Lime			15 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	13.71	13.80	.09	13.82	13.89	.07	13.92	13.97	.05	13.83	13.92	.09	13.76	13.81	.05
Pol.	11.93	11.81	.12	12.07	12.10	.03	12.24	12.22	.02	12.15	12.13	.02	12.16	12.15	.01
Sucrose	12.05	11.97	.08	12.16	12.17	.01	12.32	12 29	.03	12.21	12.19	.02	12.21	12.20	.01
Glucose	.62	.72	.10	.60	.63	.03	.59	.60	.01	.54	.59	.05	.51	.57	.06
Apt. Pty	87.02	85.58	1.44	87.34	87.11	.23	87.93	87.48	.45	87.85	87.14	.71	88.37	87.98	.39
Gr. Pty	87.89	86.74	1.15	87.99	87.61	.38	88.51	87.97	.54	88.29	87.57	.72	88.74	88.34	.40
S/G	19.44	16.63	2.81	20.27	19.32	.95	20.88	20.48	.40	22.61	20.66	1.95	23.94	21.41	2.53
S—P	.12	.16	.04	.09	.07	.02	.08	.07	.01	.06	.06	0	.05	.05	0
Phenol	.020	.025	.005	.008	.013	.005	.004	.008	.004	.002	.007	.005	.001	.007	.006
Litmus	.006	.001	.005	.008	.002	.006	.010	.004	.006	.011	.005	.006	.012	.005	.007
pH	6.91	6.58	.33	7.60	7.01	.59	8.27	7.42	.85	....	7.34	...	....	7.42	...
Inversion		Positive			Positive			Probable			Positive			Positive	

Experiment 9 at 190° F.: Positive inversion is indicated in juices 1, 2 and 3 in Experiment 9 by comparatively large increases in glucose and decreases in purities and in sucrose-glucose ratios. There are no indications of inversion in 4. Analyses of 5 indicate an increase of 0.02 in glucose but no change in purities. We have hesitated to accept this as evidence of "probable" inversion for the following reasons: Purities do not confirm the indication. In previous experiments evidence of inversion has not been found in a more alkaline juice when a less alkaline juice has shown no evidence of inversion. Such a condition, however, is found in juices 4 and 5. The increase in glucose in 5 is not beyond the maximum limit of experimental error. It seems more probable that the increase in glucose is due to an irregularity in the analyses rather than that a detectable amount of inversion has taken place. This juice has been classed as "doubtful."

Inversion was positively indicated at .008 alkalinity to litmus and 7.25 pH while at .010 alkalinity and 7.68 pH no inversion was detected.

EXPERIMENT NO. 9 AT 190°.

	1			2			3			4			5		
	5 cc Lime			7.5 cc Lime			10 cc Lime			15 cc Lime			20 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	13.85	13.85	0	13.80	13.80	0	13.90	13.85	.05	13.82	13.80	.02	14.00	14.05	.05
Pol.	12.39	12.14	.25	12.42	12.27	.15	12.55	12.40	.15	12.40	12.38	.02	12.61	12.66	.05
Sucrose	12.40	12.19	.21	12.44	12.34	.10	12.56	12.45	.11	12.42	12.41	.01	12.61	12.66	.05
Glucose	.28	.46	.22	.27	.39	.12	.25	.37	.12	.20	.20	0	.10	.12	.02
Apt. Pty	89.46	87.65	1.81	90.00	88.91	1.09	90.30	89.53	.77	89.73	89.71	.02	90.10	90.10	0
Gr. Pty	89.53	88.02	1.51	90.15	89.42	.73	90.36	89.89	.47	89.87	89.93	.05	90.10	90.10	0
S/G	44.28	26.50	17.78	46.07	31.64	14.43	50.24	33.65	16.59	62.10	62.05	.05	126.1	105.5	20.6
S—P	.01	.05	.04	.02	.07	.05	.01	.05	.04	.02	.03	.01	0	0	0
Phenol	.021	.024	.003	.010	.014	.004	.004	.008	.004	.002	.006	.004	.003	.004	.007
Litmus	...	...	...	.008	.005	.003	.012	.008	.004	.016	.010	.006	.018	.012	.006
pH	6.64	6.41	.23	7.34	6.64	.70	8.69	7.25	1.44	8.86	7.68	1.18	9.03	7.88	1.15
Inversion		Positive			Positive			Positive			None			Doubtful	

Experiment 10 at 190° F.: In Experiment 10 inversion is positively indicated in juices 1, 2 and 3 by comparatively large increases in glucose and decreases in purities and sucrose-glucose ratios. Juice 4 has been classed as "doubtful" because of an increase of 0.01 in glucose without significant changes in purities. No change in glucose is indicated in 5 and the decreases in purity by themselves are hardly large enough to class this juice as doubtful. Positive inversion has been found at .010 alkalinity to litmus and 7.34 pH, while no inversion was detected at .014 alkalinity and 7.84 pH.

EXPERIMENT NO. 10 AT 190°.

	1 — 5 cc Lime			2 — 7.5 cc Lime			3 — 10 cc Lime			4 — 15 cc Lime			5 — 20 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	14.59	14.62	.03	14.63	14.60	.03	14.79	14.76	.03	14.63	14.60	.03	14.40	14.42	.02
Pol.	13.04	12.83	.21	13.08	12.87	.21	13.24	13.20	.04	13.12	13.08	.04	12.91	12.91	0
Sucrose .	13.04	12.86	.18	13.10	12.87	.23	13.24	13.20	.04	13.12	13.10	.02	12.93	12.91	.02
Glucose .	.41	.57	.16	.41	.55	.14	.37	.42	.05	.28	.29	.01	.17	.17	0
Apt. Pty.	89.40	87.76	**1.64**	89.41	88.15	**1.26**	89.52	89.43	**.09**	89.70	89.60	**.10**	89.66	89.53	.13
Gr. Pty..	89.40	87.96	**1.44**	89.54	88.15	**1.39**	89.52	89.43	**.09**	89.70	89.73	.01	89.79	89.53	.26
S/G	31.81	22.56	**9.25**	31.95	23.40	**8.55**	35.78	31.43	**4.35**	46.86	45.17	**1.69**	76.06	75.94	.12
S—P ...	0	.03	.03	.02	.00	**.02**	0	0	0	0	.02	.02	.02	0	**.02**
Phenol ..	**.024**	**.027**	.003	**.012**	**.017**	.005	**.003**	**.008**	.005	0	**.007**	.007	.003	**.005**	.008
Litmus ..	.001	**.002**	.003	.010	.006	.004	.016	.010	.006	.020	.011	.009	.022	.014	.008
pH	6.66	6.41	.25	7.42	6.58	.84	8.77	7.34	1.43	8.86	7.68	1.18	8.94	7.84	1.10
Inversion		Positive			Positive			Positive			Doubtful			None	

Experiment 11 at 190° F.: In Experiment 11, inversion is positive in juices 1, 2, 3 and 4. Glucose has increased 0.01 in juice 5 but increases in apparent and gravity purities are indicated. This is the third of the cases where an error in a brix determination is strongly indicated by a decrease of 0.1 in brix during digestion. Comparisons indicate that the error is in the analysis before digestion. Except for this error purities would probably confirm the indication of inversion shown by the glucose determinations. This juice, however, has been classed as "doubtful." Positive inversion has been found at .002 alkalinity to litmus and 7.10 pH while none of the juices remained alkaline enough to show signs of inversion.

EXPERIMENT NO. 11 AT 190°.

	1 — 5 cc Lime			2 — 7.5 cc Lime			3 — 10 cc Lime			4 — 12.5 cc Lime			5 — 15 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	15.10	15.26	.16	14.94	14.94	0	15.04	15.04	0	15.17	15.14	.03	15.10	15.00	**.10**
Pol.	12.96	12.56	**.40**	12.87	12.52	**.35**	12.96	12.85	**.11**	13.12	13.01	**.11**	13.02	12.98	**.04**
Sucrose .	13.05	12.81	**.24**	12.97	12.71	**.26**	13.02	13.00	**.02**	13.16	13.12	**.04**	13.05	13.05	0
Glucose .	.68	1.13	.45	.68	.96	.28	.66	.78	.12	.65	.72	.07	.59	.60	.01
Apt. Pty.	85.80	82.31	**3.49**	86.15	83.80	**2.35**	86.20	85.40	**.80**	86.50	85.93	**.57**	86.20	86.53	.33
Gr. Pty..	86.43	83.95	**2.48**	86.81	85.10	**1.71**	86.60	86.40	**.20**	86.75	86.67	**.08**	86.43	87.00	.57
S/G	19.19	11.34	**7.85**	19.07	13.24	**5.83**	19.73	16.67	**3.06**	20.25	18.22	**2.03**	22.12	21.75	**.37**
S—P ...	.09	.25	.16	.10	.19	.09	.06	.15	.09	.04	.11	.07	.03	.07	.04
Phenol ..	**.014**	**.030**	.016	**.009**	**.022**	.013	**.005**	**.014**	.009	**.004**	**.012**	.008	**.003**	**.011**	.008
Litmus ..	.003	**.004**	.007	.010	.002	.012	.014	**.001**	.015	.016	.002	.014	.018	.004	.014
pH	6.24	5.65	.59	6.80	5.81	.99	7.59	5.91	1.68	8.10	7.10	1.00	8.52	7.51	1.01
Inversion		Positive			Positive			Positive			Positive			Doubtful	

Experiments 12 and 13 at 200° F.: Experiment 12 is a single sample of juice clarified to a slight alkalinity to phenolphthalein and digested at 200° for 16 hours. Experiment 13 is another juice clarified to a slight acidity to phenolphthalein and digested for 22 hours. In both cases the development of acidity has been much greater than in experiments at lower temperatures, bringing the reactions slightly on the acid side of true neutrality and as would be expected material amounts of inversion were found.

EXPERIMENT NO. 12 AT 200°.

	Before	After	Diff.
Brix	14.19	14.13	**.06**
Pol.	12.46	12.19	**.27**
Sucrose	12.48	12.26	**.22**
Glucose	.50	.65	.15
Apt. Pty........	87.81	86.27	**1.54**
Gr. Pty.........	87.95	86.77	**1.18**
S/G	24.96	18.86	**6.10**
S—P	.02	.07	.05
Phenol	.002	**.015**	.017
Litmus	.020	.004	.016
pH	9.02	6.95	2.07
Inversion		Positive	

EXPERIMENT NO. 13 AT 200°.

	Before	After	Diff.
Brix	15.10	15.11	.01
Pol.	13.90	13.39	**.51**
Sucrose	13.97	13.52	**.45**
Glucose	.25	.75	.50
Apt. Pty.	92.05	88.62	**3.43**
Gr. Pty.	92.52	89.48	**3.04**
S/G	55.88	18.03	**37.85**
S—P	.07	.13	.06
Phenol	**.002**	**.009**	.007
Litmus	.012	0	.012
pH	8.57	6.85	1.72
Inversion		Positive	

Experiment 14 at 200° F.: Owing to variation in temperature, which at times dropped as low as 195° F., the average temperature in Experiment 14 was slightly below 200° F. Reaction in the initial juices varied from a moderate alkalinity to litmus to neutrality to phenolphthalein. Development of acidity was much greater than at lower temperatures, the reactions of all the samples dropping below true neutrality.

Inversion is positively indicated in all cases.

EXPERIMENT NO. 14 AT 200°
(195-200)

	1 — 5 cc Lime			2 — 7.5 cc Lime			3 — 10 cc Lime			4 — 12.5 cc Lime			5 — 15 cc Lime		
	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.	Bef.	After	Diff.
Brix	13.95	13.95	0	13.75	13.69	.06	13.61	13.63	.02	13.82	13.78	.04	13.60	13.61	.01
Pol.	12.58	12.27	.31	12.44	12.08	.36	12.42	12.02	.40	12.51	12.38	.13	12.39	12.28	.11
Sucrose	12.64	12.41	.23	12.51	12.18	.33	12.49	12.12	.37	12.56	12.47	.09	12.44	12.34	.10
Glucose	.41	.67	.16	.41	.65	.14	.41	.66	.15	.28	.37	.09	.20	.27	.07
Apt. Pty	90.18	87.96	2.22	90.50	88.24	2.26	91.26	88.20	3.06	90.52	89.84	.68	91.11	90.23	.88
Gr. Pty	90.61	88.96	1.65	91.00	89.00	2.00	91.77	88.92	2.85	90.90	90 50	.40	91.47	90.67	.80
S/G	30.83	18.52	12.31	30.51	18.74	11.77	30.46	18.36	12.10	44.86	33.70	11.16	62.20	45.70	16.50
S—P	.06	.14	.08	.07	.10	.03	.07	.10	.03	.05	.09	.04	.05	.06	.01
Phenol	.007	.015	.008	.004	.012	.008	.003	.013	.010	.003	.011	.008	0	.012	.012
Litmus	.008	...	...	.010	...	...	.011	...	...	.012	....	...	.014	....	...
pH	7.68	6.24	1.44	8.27	6.14	2.13	8.35	6.07	2.28	8.40	6.49	1.91	8.89	6.75	2.14
Inversion	Positive			Positive			Positive			Positive			Positive		

Experiment 15 at 212° F.: In Experiment 15 a sample of clarified juice was kept at the boiling point under a reflux condenser. Acidity developed rapidly. In six hours inversion is positively indicated. In twenty-two hours approximately a quarter of the total sucrose had been inverted.

At 200° and 212° F., development of acidity was so rapid that material quantities of sucrose were inverted even with initial reactions as alkaline as is at all desirable in factory practice. As it appeared impossible to maintain juices without inversion through the digestion period no further experiments were run at these higher temperatures.

EXPERIMENT NO. 15 AT 212°.

	Before	After 6 Hours	After 22 Hours
Brix	13.32	13.30	13.37
Pol.	10.40	10.28	7.13
Sucrose	10.63	.....	8.01
Glucose	1.60	1.66	4.26
Apt. Pty	78.08	77.30	53.33
Gr. Pty.	79.81	.....	59.91
P/G	6.50	6.19	1.67
S/G	6.64	.....	1.88
Phenol.	.002	.....	.020
Litmus	.018	.....	.018
pH	8.80	6.58	5.22
Inversion		Positive	Positive

Development of Acidity

The preceding data indicates that development of acidity is such an important characteristic of juices at high temperatures that it is necessary to consider it before discussing inversion of sucrose or destruction of glucose. We would again note that reactions have been measured in three different ways: litmus titration, phenolphthalein titration, and hydrogen ion concentration. The first two are quantitative measurements, that is, measurements of total quantities of acid without particular reference to activity or ionization, as, in electrical measurements, watts measure the total quantity of current irrespective of its power to overcome resistance. Hydrogen ion concentration measurements refer only to that portion of the acid which is actually ionized or active without reference to the total quantity, as, again referring to electrical measurements, volts indicate ability to overcome resistance without reference to quantity.

Acid acts as a catalyzer in the hydrolysis of sucrose, that is, it causes the inversion of sucrose without being consumed. In such a reaction the degree of ionization or activity of the acid is of much greater importance than the quantity. However, as practically all data for acidity or alkalinity in factory practice are titration figures, we will first consider the development of acidity on this quantitative basis.

Development of total acidity at different initial reactions in the experiments at 180° F., on the basis of titration figures, is arranged graphically in Fig. 1. Higher temperatures have not been included, because data are not sufficient to bring out this relation.

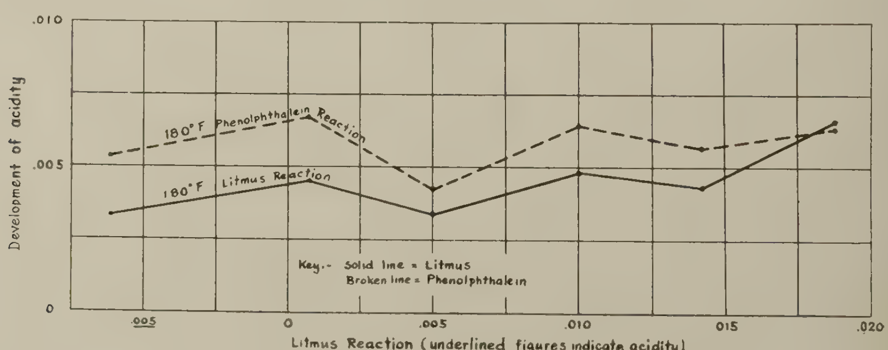

Fig. 1

The scale at the bottom is the litmus reaction of the juices before digestion. Juices with initial reactions within each range of .005, referred to litmus, have been averaged together and the points representing increases in acidity plotted on ordinates corresponding to this original litmus reaction. Development of acidity, indicated by phenolphthalein titration in the same juices, is plotted on the same ordinates. Development of acidity at different reactions, as shown by titration with either indicator, is indicated by the distances from the base line to the corresponding curve.

The curve for litmus titration indicates somewhat of a tendency toward greater development of acidity in the more alkaline juices. According to the phenolphthalein curve, however, there is little difference between alkaline and acid juices, and certainly no marked tendency towards greater development of acidity in the more alkaline juices.

Data from the preceding experiments on the effect of temperature on the development of total acidity during digestion are in the following tabulation. Both litmus and phenolphthalein titrations have been averaged together, as we wish to give a general idea of the effect of temperature, rather than to develop exact quantitative relations.

Temperature	No. of Determinations	Development of Acidity in 22 Hours
180° F.	80	.0054 per cent CaO
190° F.	29	.0074 " " "
200° F.	9	.0109 " " "
212° F.	2	.0270 " " "

Though the amount of data at 200° and 212° F. is comparatively small, the above figures are sufficiently conclusive to show that the rate at which total acidity develops is dependent on the temperature, increasing rapidly as the temperature increases.

Development of acidity on the more significant basis of hydrogen ion concentration has been plotted in Fig. 2. Data for 212° F. have not been included, as but one experiment is available at this temperature. In this experiment, the increase in hydrogen ion concentration per liter in twenty-two hours was .000,005 grams. To plot this point on the scale used, the graph would have to be extended to between nine and ten times its present height.

The curves for increase in hydrogen ion concentration in Fig. 2 show that at a given reaction the development of acidity increases with increases in temperature. At a given temperature, the more alkaline juices show the smallest development of acidity, while as acid reactions are approached development of acidity becomes very much greater. The curves are sufficiently conclusive to justify the latter conclusion notwithstanding irregularities in the curves for 190° F. and 200° F. In these curves increases in hydrogen ion concentration is less in the most acid juices than in the group of juices represented by the next point on the alkaline side. This may be significant, or it may be on account of the comparatively small amount of data available at these points. In this connection it might be noted that the hydrogen ion concentration curve for 180° F., representing a much greater amount of data, gives no indication of such an irregularity.

Though so far as we can judge from available publications, development of acidity has received little if any attention in investigations on juices, it has been generally recognized in factory practice. Here it has been sometimes ascribed to bacterial action but more often to the destructive action of lime on glucose.

Bacterial action can and does cause development of acidity at temperatures sufficiently low for bacteria to develop. It cannot be the cause at temperatures above the thermal limit of vegetative growth of the organisms found in juices. Temperatures in these experiments have been far enough above the latter point to preclude the possibility that bacterial action was a factor contributing to the development of acidity found.

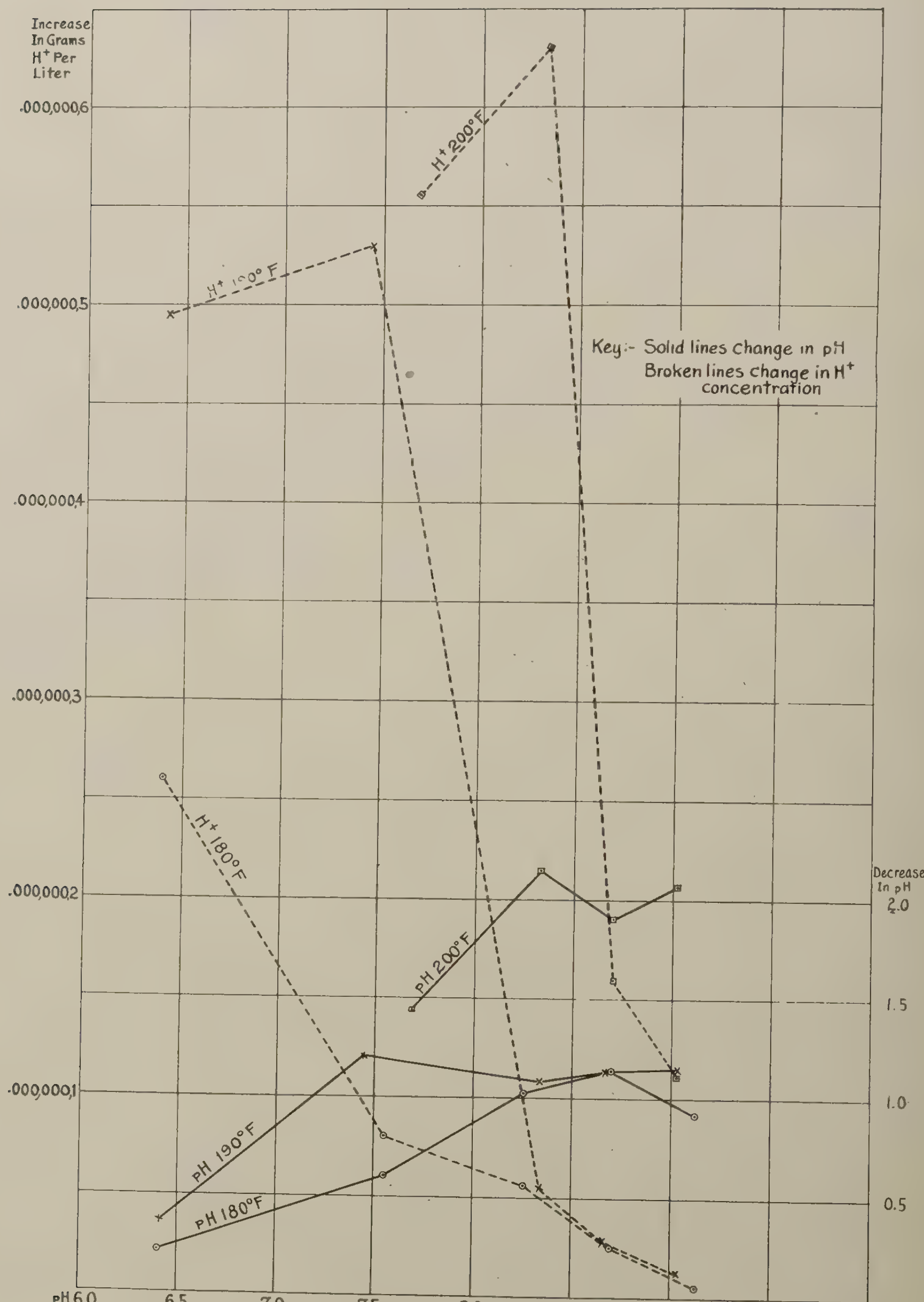

FIG. 2.

As in Fig. 1, juices with initial reactions within somewhat narrow ranges, have been averaged together. The scale at the bottom is the pH value of the juices before digestion. Solid lines are pH values after digestion, referred to the scale on the right. Distances of points on the solid lines above the base line thus indicate decreases in pH during twenty-two hours' digestion and the intersection of an ordinate on which a point is plotted with the base line is the pH of the juices represented by this point before digestion.

The pH units are logarithmic functions, used because of the awkwardness of actual

In the presence of large amounts of alkali, that is at very low hydrogen ion concentrations, without doubt glucose would be destroyed and at least a part of the development of acidity would be due to this factor. Here, however, we are considering the range of reactions covered by these experiments. This includes alkalinities up to 9 or 10 pH, which we consider as alkaline as it is necessary to consider when investigating cane sugar factory problems. References in this article to alkaline juices are to juices not exceeding this limit. Our data do not give us information on changes that may take place at abnormal alkalinities.

According to the theory that development of acidity is due to the formation of acid products, the result of the destructive action of lime on glucose, we would expect little or no development of acidity in acid juices, it being confined largely to alkaline juices and increasing with increase in alkalinity. The litmus curve in Fig. 1 does show a fairly pronounced tendency toward greater development of acidity in the more alkaline juices, and as litmus has been the indicator most frequently used in factory control, this may be a reason why the above theory has been so widely accepted. Contrary to what would be expected were this theory correct, the litmus curve in Fig. 1 indicates material development of acidity even in the most acid juices and the tendency towards greater development of acidity in the more alkaline juices is by no means as pronounced as would be expected. Further, the phenolphthalein curve shows this tendency to a slight extent only, if at all. Also to comply with this theory, glucose should be destroyed and of this there is very little evidence in these experiments. On the whole, titration figures in these experiments afford little, if any, confirmation for the theory that development of acidity is due to the destructive action of alkali on glucose.

On the more significant basis of hydrogen ion concentration, development of acidity, instead of being greater in the alkaline juices, is very much greater at acid reactions.

Research in the canning industry also has demonstrated that development of acidity at high temperatures is a characteristic of most, if not all, fruit and vegetable juices, taking place even when they have not been treated with alkali.

The theory that development of acidity in juices is due to the destruction of glucose by alkali can hardly be correlated with the above, so, within the range of reaction covered by these experiments, which includes the range practicable in factory operation, we have concluded that destruction of glucose is not the cause of development of acidity. Several possible causes have been considered, but so far we have failed to find an explanation in reasonable agreement with the observed facts.

Development of acidity is a factor which renders the investigation of such changes as inversion of sucrose and destruction of glucose in juices most difficult.

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figures for hydrogen ion concentration. The difference between seven and eight pH is ten times the difference between eight and nine, the difference between six and seven is, in turn, ten times the difference between seven and eight. While the pH scale is very convenient for ordinay use, it is difficult to grasp the exact significance in a case such as is presented by this graph. In order to bring the exact relationship out more clearly, increases in hydrogen ion concentration are shown by dotted lines, referring to the scale on the left. Points on the dotted lines representing increases in hydrogen ion concentration are plotted on the same ordinates as corresponding points for decreases in pH.

We have so far been unable to devise methods for directly determining the rate at which sucrose is inverted at a given reaction, for we cannot maintain the juice at the desired reaction, and because of development of acidity, the rate of inversion is constantly changing as the experiment proceeds. Defining the exact reaction at which juices, from a standpoint of factory operation, may be considered safe from inversion, is rendered equally difficult by this factor. By the time sufficient sugar has been inverted to detect the change with available analytical methods, the juice has become more acid than the point at which, for practical purposes, inversion might be considered as starting. Development of acidity similarly affects obtaining accurate data on destruction of glucose, though in this case the change in reaction is such that the rate at which glucose is destroyed should decrease as the experiment proceeds instead of increasing as in the case of inversion of sucrose.

Destruction of Glucose

Changes in glucose occurred during the preliminary clarification of the samples. In some of the more acid juices, glucose increased, but at more alkaline reactions, glucose disappeared; destruction of glucose in some of the more alkaline samples amounting to a fairly large proportion of the glucose in the original juice. We are considering, however, destruction of glucose during the subsequent digestion of the clarified juices and not destruction of glucose during clarification.

A decrease in glucose is found in only one of the preceding experiments. This is juice 5 in Experiment 4, where the decrease is 0.02. As this decrease is hardly beyond the maximum experimental error, and as a number of other juices were digested at even higher alkalinities and at higher temperatures without decreases in glucose, we have hesitated to accept this single instance as positive evidence that glucose has been destroyed.

If any material amount of glucose has been destroyed, there should be losses of total sugars during digestion. The following are averages for total sugars before and after digestion in all experiments, after correcting for a slight amount of evaporation during digestion, and the effect of the formation of glucose on the density:

	Before Digestion	After Digestion
Sucrose	12.695	12.561
Glucose originally present	0.641	0.641
Increase in glucose (calculated back to sucrose)	......	0.136
Total sugars	13.336	13.338

According to these figures total sugars in the initial samples are fully accounted for in the samples after digestion.

Further evidence of a negative character are data for development of acidity previously discussed. Assuming that alkalinities would be reduced if glucose were destroyed by lime, data for development of acidity do not coincide with what would be expected if glucose had been destroyed through heat and excessive alkalinity.

From the above we can conclude that though glucose was in most cases destroyed during clarification there is no evidence that it was destroyed to an appreciable extent during further digestion under the conditions of these experiments even at initial reactions considerably more alkaline than the neutral point to phenolphthalein.

Nearly all of the juices in these experiments were of normal composition, but few of them containing more than 1 per cent glucose. The above conclusion does not preclude the possibility that detectable destruction of glucose might take place under the conditions of these experiments at high glucose concentrations, particularly at the higher temperatures.

Inversion of Sucrose

Table 1 is a recapitulation of the more significant data in the preceding experiments on inversion of sucrose, as in the preceding tabulations decreases are in dark-face and increase in light-face figures. Reactions are expressed in pH values only, for after careful examinations it seems evident that the indications of both litmus and phenolphthalein titrations are so variable that they cannot be used as a basis for at all close conclusions as to the reactions at which inversion may be detected.

TABLE I.

		Positive				Probable				Doubtful				Not Detected			
Experiment	Temperature	Final pH	Change in Ap. Pty.	Change in Gr. Pty.	Change in Glucose	Final pH	Change in Ap. Pty.	Change in Gr. Pty.	Change in Glucose	Final pH	Change in Ap. Pty.	Change in Gr. Pty.	Change in Glucose	Final pH	Change in Ap. Pty.	Change in Gr. Pty.	Change in Glucose
1	180	7.68	.13	.21	.02	....	....	....	....	....	....	....	....	8.18	.09	.41	0
2	180	6.86	.30	.24	.04	....	....	....	....	....	....	....	....	7.25	.14	.21	.01
3	180	7.25	.20	.27	.04	7.51	.01	.20	.01	....	....	....	....	....	....	....	....
4	180	6.15	1.33	.79	.14	....	....	....	....	7.22	.43	.43	0	7.59	.06	0	.02
5	180	7.25	.26	.33	.04	....	....	....	....	7.51 7.76	.01 .42	0 .57	.01 .01	8.01	.07	.01	0
6	180	7.17	.20	.20	.02	....	....	....	....	7.25	.72	.65	.01	7.34	.06	0	0
7	180	....	1.30	1.00	.05	....	....	....	....	....	....	....	....	....	0	.18	0
8	180	7.42	.39	.40	.06	7.42	.45	.54	.01	....	....	....	....	....	....	....	....
9	190	7.25	.77	.47	.12	....	....	....	....	7.88	0	0	.02	7.68	.02	.05	0
10	190	7.34	.09	.09	.05	....	....	....	....	7.68	.10	.01	.01	7.84	.13	.26	0
11	190	7.10	.57	.08	.07	....	....	....	....	7.51	.33	.57	.01	....	....	....	....
12	200	6.95	1.54	1.18	.15	....	....	..	....	....	....	....	....	....	....	....	....
13	200	6.85	3.43	3.04	.50	....	....	....	....	....	....	....	....	....	....	....	....
14	200	6.75	.88	.80	.07	....	....	....	....	....	....	....	....	....	....	....	....
15	212	5.22	24.7	19.9	4.26	....	....	....	....	....	....	....	....	....	....	....	....

The most alkaline juice in each experiment in which inversion has been designated as positive, has been tabulated under the heading "Positive." Similarly in an experiment in which inversion has not been detected, the least alkaline juice in which evidence of inversion has not been found is tabulated under the heading "Not Detected." All juices in which inversion has been designated as "Probable" and "Doubtful" are tabulated under the appropriate headings. The pH figures are for reactions at the end of the digestion period.

Definite conclusions as to the reaction at which detectable inversion may be found can hardly be drawn from data in the "Positive" column for in all cases, except two, inversion has proceeded considerably further than what we have accepted as minimum evidence of positive inversion. This is particularly true of the experiments at 200° and 212° F. where the pH has dropped below 7 and considerable inversion has taken place. Six out of eight of the juices in experiments at 180° and 190° F. tabulated in this column are more alkaline than 7 pH. The particular significance of data in this column is that inversion occurred before the juice had decreased in alkalinity to the true neutral point.

Considering next the least alkaline juices in which the analyses failed to detect evidence of inversion, we find one at 7.25 pH, one at 7.34 pH and the remainder between 7.5 pH and 8.2 pH. The particular significance of data in this column is that at higher alkalinities inversion has not been detected. It is improbable that evidence of inversion will be found in juices held at high temperatures before the alkalinity decreases to below 8 pH.

In the "Probable" column we find fairly definite evidence of inversion at 7.42 pH and 7.51 pH. In the "Doubtful" column which includes juices in which analyses have shown some evidence of inversion, though not to the extent that a conclusion that it had been detected seems justified on the strength of single analyses, pH values vary from 7.22 to 7.88. On the whole, it seems reasonable to conclude that by the time a juice is held at high temperatures till the alkalinity has dropped to a point within this range, evidence of inversion should begin to appear.

The most significant features of data in this table, which we wish to particularly emphasize, are: First, inversion has been positively demonstrated in juices alkaline to litmus and on the alkaline side of true neutrality. Second, at still higher alkalinities, although still on the acid side of neutrality to phenolphthalein inversion has not been detected.

Where data can be averaged and plotted more reliable deductions may be drawn than from tabulated data such as in Table 1. Experiments at 180° and 190° F., taken together furnish sufficient data to secure reasonably satisfactory averages notwithstanding difficulties inherent in obtaining valid averages of this kind of data. These are plotted in Fig. 3, where changes in glucose in experiments at 180° and 190° F. are plotted against pH values after digestion. Hydrogen ion concentrations, expressed in grams per liter, designated H^+ are also given beneath the corresponding pH. Average points at which neutrality to litmus and the faintest detectable pink color with phenolphthalein have been observed in juices are also indicated. The curve gives a slight indication of inversion as high as 8 pH but no indication that inversion has taken place at still higher alkalinities. At 7.5 pH the indication becomes quite definite. At still lower pH values the amount of inversion increases rapidly.

Two theories relating to inversion of sucrose have been quite generally accepted in the cane sugar industry. The first is that inversion through acidity does not take place at moderate acidities. The second is that inversion is caused by heat independent of acidity.

We are unable to trace the origin of the first of the above theories and so do not know in what sense the term acidity is used; that is, whether it refers to

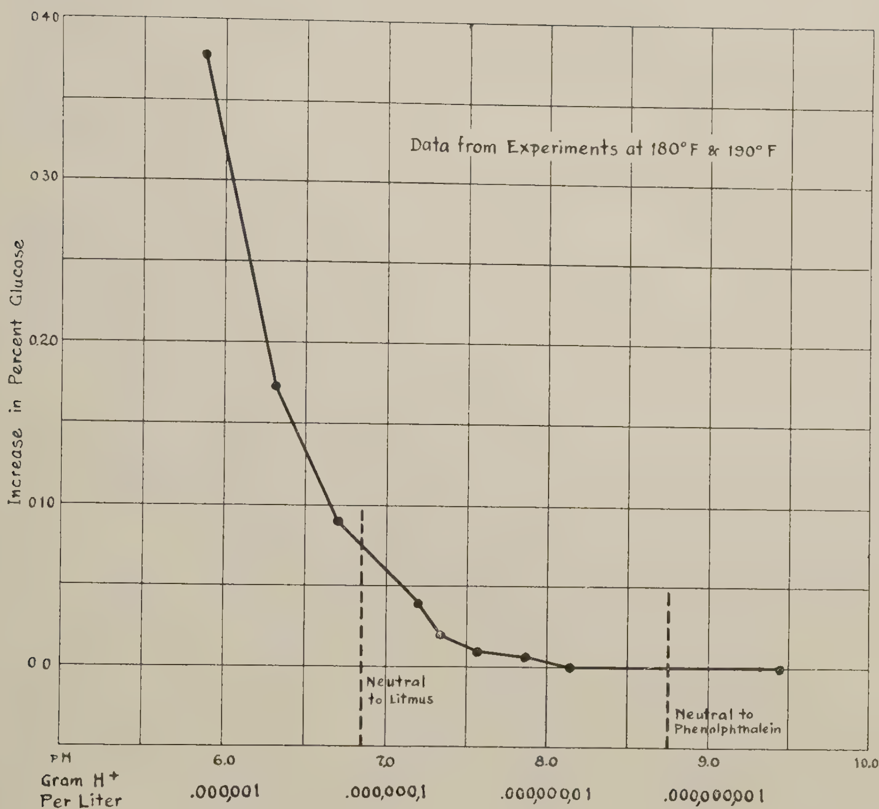


FIG. 3.

litmus, to phenolphthalein, or to other indicators. If phenolphthalein is referred to, the theory has some foundation in fact, for within a narrow range on the acid side of the neutral point to phenolphthalein in juices inversion, if occurring at all, takes place to such a slight extent that we were unable to detect it in these experiments. In factory practice, this theory has been quite generally accepted as referring to litmus. On this basis, data we have presented demonstrate that it is most misleading, detectable inversion being found not only in juices alkaline to litmus but also in juices on the alkaline side of true neutrality.

The theory that inversion of sucrose is caused by heat appears to have its origin in work on unbuffered solutions, in connection with which hydrogen ion concentration measurements were not made. Sugar in common with most organic substances is destroyed at sufficiently high temperatures. If inversion through heat occurs at temperatures below the boiling point it should have been found in the more alkaline juices in these experiments. As inversion was not detected in these juices we have concluded that within the range of temperatures covered by these experiments, the theory that "heat" causes any material inversion of sucrose in juices is without foundation.

Scientific investigation has demonstrated that in unbuffered or lightly buffered solutions, within the range of hydrogen ion concentrations covered by these experiments and at a given concentration of sucrose, inversion is approximately

proportional to the hydrogen ion concentration. This theory might be visualized by considering the hydrogen ions and sucrose molecules in motion in a solution and inversion occurring in proportion to the number of collisions between the two.

The above theory agrees well with the results secured in these experiments. Indeed it is difficult to account for what has been found on any other basis. The modern conception of neutrality is that hydrogen and hydroxyl ions are present in equal concentrations, not the absence of ions. In passing from neutrality to alkalinity, that is from 7 to higher pH values, there is an increase in the hydroxyl ion concentration and a corresponding decrease in the concentration of hydrogen ions. This decrease is in quantity. There is little reason to believe that the activity of the remaining hydrogen ions is changed. On this basis we have a satisfactory explanation of the inversion noted in alkaline juices.

The curve in Fig. 3 also supports this theory. While increases in glucose are plotted against final, and not average reactions, when we take into consideration the more rapid increase in hydrogen ion concentration as acid reactions are approached, average reactions during the digestion period may be somewhat roughly inferred. On this basis there is a sufficiently consistent relation between inversion and hydrogen ion concentration to lend considerable support to the theory that inversion of sucrose is in proportion to hydrogen ion concentration.

Summary

We are not so interested in developing theories, however, as in obtaining reliable information on which to base factory practice. From this point of view these data on the characteristics of hot clarified juice may be summed up as follows:

First: Development of acidity is constantly taking place. Increase in hydrogen ion concentration is much more significant from the standpoint of factory operation than quantitative development, shown by titration figures. Increase in hydrogen ion concentration is at a minimum velocity at higher alkalinities and lower temperatures, the velocity increasing as alkalinities are reduced and also as temperatures are increased.

Second: Though glucose is destroyed when juices are clarified at alkaline reactions, further destruction of glucose to a detectable extent does not take place on further digestion under the conditions of these experiments.

Third: Inversion of sucrose takes place at high temperatures in moderately alkaline juices. At still higher alkalinities we have not been able to detect it. It seems quite probable, however, that under otherwise equal conditions, inversion of sucrose is in proportion to hydrogen ion concentration.

We have previously noted that from the standpoint of raw sugar factory operation, a "neutral zone" might be defined as a range of reactions where sucrose is not inverted and glucose is not destroyed; or if these changes take place at all they proceed slowly enough so that their effect is negligible. It was also pointed out that in juices such a zone must be at temperatures above 160° or 165° F. because at lower temperatures bacteria can develop and destroy both glucose and sucrose as any reaction practicable in raw sugar factory practice.

The following discussion of such a zone is with reference to that portion of the process to which the results of this investigation are directly applicable. This is from the juice heaters until lower temperatures and higher concentration are reached in the evaporators. These data are not so directly applicable beyond the evaporators where higher concentrations, lower temperatures, and volatilization of acid products from boiling liquors introduce factors not taken into consideration in these experiments.

Destruction of glucose has not been demonstrated, so with reference to this factor, at least in juices of moderate glucose content, the neutral zone may extend to the limit of alkalinity covered by these experiments. This is at least 9.5 pH.

If inversion of sucrose is in proportion to hydrogen ion concentration a zone in which no inversion of sucrose takes place will not be found. On the basis of the curve in Fig. 3, however, it would appear that above 7.8 or possibly 8.0 pH, inversion proceeds so slowly that it may be considered negligible, while at a more acid reaction than this it becomes appreciable. We, therefore, tentatively define a "neutral zone" in which destruction of both sucrose and glucose is negligible as from about 7.8 pH to the limit of alkalinity covered by these experiments.

The above has been qualified as tentative for the following reasons:

First: These experiments were planned primarily to obtain a general idea of the characteristics of hot clarified juice. On account of developments of acidity the methods employed have not been suitable for obtaining data enabling us to calculate the rate of inversion at a given reaction. It has been necessary to form an opinion as to the reaction where inversion becomes negligible from the amount of inversion found at the end of an experiment in which the reaction was constantly changing. In this connection we would note that an increase of 0.01 in glucose is equivalent to the destruction of slightly less than 0.1 per cent of the sucrose in a juice.

Second: Data at 200° and 212° are incomplete. There were very few experiments at these temperatures because it was impossible to carry juices through the digestion period without inversion. Inversion of sucrose is much faster at higher temperatures. Deerr gives the following figures for the effect of temperature on the rate of inversion: *

Temperature ° C	Relative Inversion Rate
25	1
50	26.7
70	282
80 (176° F.)	814
90 (194° F.)	2110
100 (212° F.)	5659

Without doubt temperature has a similar influence on the rate at which glucose is destroyed. More accurate information on inversion rates at given hydrogen ion concentrations and at higher temperatures, which is now being secured, may render it necessary to modify to some extent the above limits of the neutral zone.

* Cane Sugar, page 262.

While destruction of glucose does not impose an alkaline limit on our neutral zone, in factory practice another consideration definitely limits the alkalinity. Previous work on clarification has shown that the maximum purification is secured when the juice, after it has passed through the heater, is approximately 8.6 pH to 8.8 pH. Additions of lime beyond this point cause undesirable decreases from the maximum purity.

If juices are clarified at the optimum reaction there is a margin of about one point pH for development of acidity before reactions are reached where appreciable inversion need be feared. How much the acidity develops depends on how high the temperatures are and how long the juice is subjected to these high temperatures. Under ordinary operating conditions juices clarified at the optimum reaction can be worked through to where lower temperatures are encountered in the evaporators before the reaction drops to 7.8 pH. In this case no appreciable inversion will be sustained in this part of the process. If the reaction becomes more acid than this it is practically certain that some inversion will take place.

In many factories the large volume of settlings resulting from an alkaline clarification overloads the filtration equipment and prevents liming to the optimum reaction. This is particularly true when the juices worked are those from which it is possible to secure the best results in clarification. If the reaction of the heated juice is below the lower limit of the "neutral zone," appreciable inversion is undoubtedly going on from the time the juice leaves the heater. It must also be remembered that development of acidity is faster in such juices than in those clarified at a more alkaline reaction. Under such conditions some loss appears inevitable. It may be reduced to the extent that temperatures can be lowered and the time juices are exposed to high temperatures shortened. These expedients, however, are probably of limited application.

Results secured in these experiments may be applied directly to the problem of keeping juices without loss during shutdowns. Except that in these experiments, temperatures were constant while in the settling tanks temperatures are dropping, conditions during these experiments are identical with those when juices are held over. The principal factors which must be considered are two: bacterial action and development of acidity. The tanks must be sufficiently well insulated so that temperatures in all parts of them are maintained above 160 to 165 degrees. If it drops below this, losses through bacterial action may be expected. Development of acidity must be retarded by reducing the temperature at which the tanks are filled. If the juice is limed so that the hot juice is about 8.6 to 8.8 pH and the temperature is low enough so that the pH does not fall below a point somewhere between 7.5 and 8.0, losses will be negligible. This fully confirms and explains H. S. Walker's observations at Pioneer Mill. The temperature drop in the settling tanks at this factory averaged .5° F. per hour. By liming the juice to about the optimum reaction and filling the tanks at 180° F., juice could be held for 24 or 36 hours without appreciable loss.

While the results of this investigation on the whole are at variance with many of the usually accepted theories in cane sugar factory practice, they are thoroughly

in agreement with the time-honored axiom that sugar should be worked through the process as rapidly as possible.

Further work to secure quantitative data of greater precision is now being carried on in this laboratory on the basis of the general characteristics herein developed. All our investigation of clarification, particularly that presented in this article, strongly indicates the need of better means for controlling reactions in factory practice. Developing methods for determining hydrogen ion concentration, so that it will be practicable to use them in routine factory work, is included in the work now being carried on.

Weeding Railroad Tracks in the Tropics*

By R. E. Vanderbilt

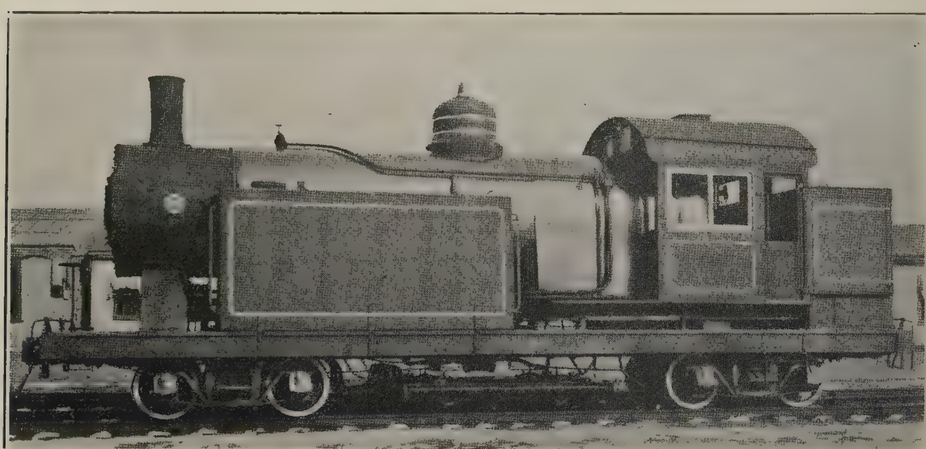
One of the important matters to which almost every railroad must devote attention in a greater or less degree is that of keeping its right of way cleared of vegetation; that is, of grass and weeds, which often seem determined to grow where they are least wanted. The roads operating in our temperate zones spend annually large sums in cleaning their tracks, but in the tropics, where the weather is always warm or hot and the rains copious, the problem assumes much greater proportions. In the earlier days of railroading all the weeding was done by laborers who either plucked the vegetation out by hand or scratched it out with hoes and shovels; and even now this method is used by most roads througohut the world.

However, it is of interest to note that within the last few years, certain roads have by study and experimenation developed other methods of weeding that are far more effective and economical than the hand method. These new processes, which are successful in varying degrees according to local conditions, fall generally into three classes as follows: chemical, fire and superheated steam. The chemical process consists in spraying the vegetation with a poisonous solution which causes it to wither and fall to the ground, while the apparatus used includes a suitable car fitted with tanks, spraying device and the necessary control apparatus. The fire process, as the name we have given it implies, involves the burning of the weeds and grass with an oil fire supplied with fuel from a tank and spraying feature located on a special car. The superheated steam process depends, for its effect, upon subjecting the vegetation to a storm of highly superheated steam, usually with a temperature of 700° F. or more, which penetrates to the roots. To do this requires a boiler and superheater of liberal capacity, properly mounted on a car with water and fuel space. All three types of apparatus depend upon a locomotive for their movement.

In the United States, perhaps the most popular process is the chemical, although it is rightfully objected to in many regions because of the deaths result-

*From Baldwin Locomotives, April, 1924.

ing among livestock which eat the poison-covered weeds, this mortality rate often far exceeding that due to the striking of the animals by passing trains. However, there are many other regions in which this objection does not exist, because of the variety of our industries in different parts of the country. The The fire process, being less effective as a permanent weed destroyer and more injurious to wooden ties, is comparatively little used, notwithstanding it is a cheaper method than hand weeding. The superheated steam weed destroyer, being the most effective of the three methods and the least injurious to livestock and the woolen ties, finds greatest favor where these features are most required; namely, on the tropical railroads where track vegetation grows tall and strong and also very rapidly; where cattle, goats and horses graze almost without restriction, and where the exposed ties offer so much chance to destroy the track by fire. This last statement leads us to the thought suggested in our title, which is, to give a short discussion of how one or two tropical companies are using superheated steam most successfully, and to describe some apparatus recently built for the purpose.

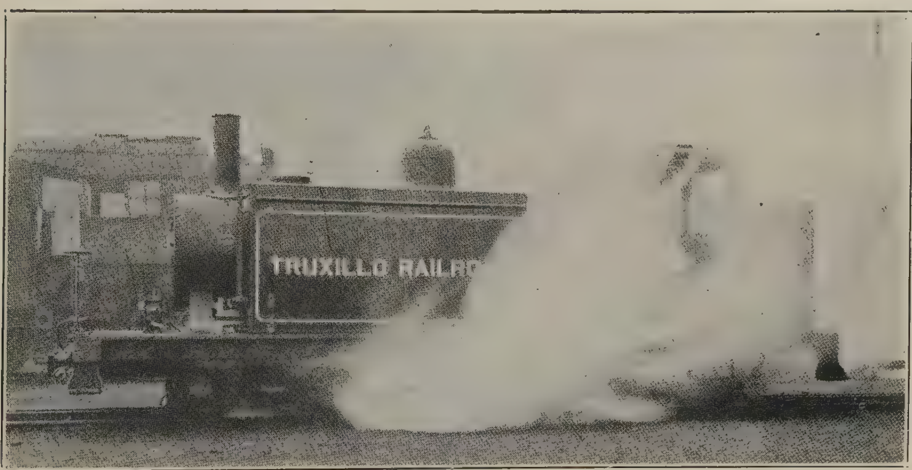


Side view of weed destroyer in use by Cuba Northern Railway Company.

To the railway operating officials of the United Fruit Company in Panama, Costa Rica, Honduras and Cuba belongs most of the credit for the development of a cheap weeding process in the tropics. These men, whose duty it is to transport from the interior farms and plantations to the seaports the fruits and sugar produced, faced the problem of cleaning many miles of track and have solved it to the extent that each year now with the superheated steam destroyers show a vast saving over the years when hand cleaning was resorted to. For example, the Northern Railway Company of Costa Rica reported in 1922 that their yearly cost per mile for hand weeding had been $82.50, while the corresponding cost with superheated steam was $13.92, showing a saving of $68.58 per mile per year or about 83 per cent of the cost for hand weeding. Equally pleasing results have been accomplished by the Truxillo Railroad of Honduras who reduced their cost of $49.20 per kilometer to about $3.00 per kilometer.

For the most part the apparatus used by these roads has been made by their own shop forces from parts already on hand or purchased from the Baldwin Locomotive Works. It has been shown possible to operate a weed destroying train satisfactorily with one engineer, one fireman, two brakeman, and one night hustler, this crew handling both the weed burner and the locomotive propelling it. The men sleep in a camp car which is carried along, and eat at the most convenient places along the line. At night the entire staff ties up at the nearest siding. The speed of travel is usually 2 miles per hour for the best results.

The accompanying photographs illustrate an apparatus recently built by the Baldwin Locomotive Works for use on the lines of the Cuba Northern Railways Co. As can be seen, the boiler is of the locomotive type, firmly anchored to a saddle casting at the front and supported on expansion pads at the back end, with superheater built in as in locomotive practice. A fuel oil tank is provided at the rear of the car while water tanks appear at either side of the boiler barrel. Feed water is handled by two injectors, which discharge into the boiler through a double top check. Draft is induced by means of an efficient brass nozzle in the smoke box directing a jet of steam upward through the cleaning pipe and stack with its control permitted by an ordinary blower valve in the cab.



Truxillo Railroad Company's Weed Destroyer Under Steam Test.

To support and carry the weight of this liberal sized boiler, as well as the water and fuel tanks, a flat car of sturdy construction had to be furnished. Structurally, the underframe includes center sills of 15″, 70 lb. eye beams and side sills of 12″, 50 lb. channels, strongly braced. The trucks likewise are for heavy duty, having 6″ x 11″ journals and 33″ rolled steel wheels. The equipment covers such refinements as roller side bearings for the trucks, combined air and hand brake, and spring draft gear.

The actual spraying of the superheated steam over the weeds and grass is accomplished by the large, square, pan-shaped part shown suspended from the car frame between the two trucks. Briefly, this part, known as the grid, consists of a series of ¾″ iron pipes, symmetrically spaced and perforated for the direc-

tion of the steam down to the roots of the vegetation. After leaving the main throttle in the boiler dome the steam passes through the dry pipe and superheater, through steam pipes in the smoke box and saddle casting, hence through three flexible branch pipes in the grid. As to discharge arrangement, the grid is divided into three sections, one lying between the rails, another outside of the right hand rail and the third outside of the left hand rail. Each of these sections receives its steam through a separate branch pipe from the main supply so that by means of stop cocks in the branch pipes which are operated with levers in the cab, it is possible to burn the weeds selectively, according to where the greatest need appears. Naturally it is important to retain as much heat as possible in the steam until it actually leaves the grid, and to accomplish this all open supply pipes as well as the top of the grid itself, are heavily lagged with asbestos. Also, to aid in confining a large quantity of hot steam over the area, the builders provided an extra heavy canvas curtain which, though not shown in the photo, is arranged for hanging around the outside of the grid.

Much interest is being shown in the apparatus by tropical railroads and a rapid adoption of it as standard equipment in the future is predicted.

[H. P. A.]

Sugar Prices.

96° Centrifugals for the Period

June 16 to September 12, 1924.

Date	Per Pound	Per Ton	Remarks
June 16, 1924.....	5.2133¢	$104.27	Porto Ricos, 5.15, 5.28; Philippines, 5.21.
" 17..........	5.215	104.30	Cubas, 5.15; Philippines, 5.28.
" 19..........	5.28	105.60	Cubas.
" 26..........	5.34	106.80	Cubas.
" 27..........	5.37	107.40	Cubas, 5.40; Porto Ricos, 5.34.
" 30..........	5.34	106.80	Philippines.
July 1..........	5.28	105.60	Spot Philippines.
" 2..........	5.21	104.20	Spot Philippines.
" 7..........	5.15	103.00	Porto Ricos.
" 9..........	5.055	101.10	Spot Cubas, 5.09; Spot Philippines, 5.02.
" 10..........	5.09	101.80	Philippines.
" 14..........	5.15	103.00	Porto Ricos.
" 15..........	5.18	103.60	Cubas, 5.21; Porto Ricos, 5.15.
" 17..........	5.02	100.40	Cubas.
" 23..........	5.055	101.10	Cubas, 5.02; Philippines, 5.09.
" 24..........	5.15	103.00	Spot Cubas.
" 28..........	5.09	101.80	Philippines.
" 31..........	5.02	100.40	Cubas.
Aug. 6..........	5.055	101.10	Cubas, 5.02, 5.09.
" 7..........	5.12	102.40	Cubas.
" 11..........	5.18	103.60	Philippines, 5.15; Cubas, 5.21.
" 12..........	5.21	104.20	Cubas.
" 14..........	5.28	105.60	Cubas.
" 15..........	5.40	108.00	Cubas.
" 18..........	5.4933	109.87	Cubas, 5.46, 5.53, 5.49.
" 19..........	5.46	109.20	Cubas.
" 20..........	5.53	110.60	Cubas.
" 26..........	5.495	109.90	Cubas, 5.46, 5.53.
" 28..........	5.65	113.00	Spot Cubas.
Sept. 3..........	5.78	115.60	Cubas.
" 8..........	5.90	118.00	Cubas.
" 9..........	5.93	118.60	Cubas, 5.90, 5.96.
" 10..........	6.03	120.60	Cubas.
" 12..........	5.96	119.20	Cubas.

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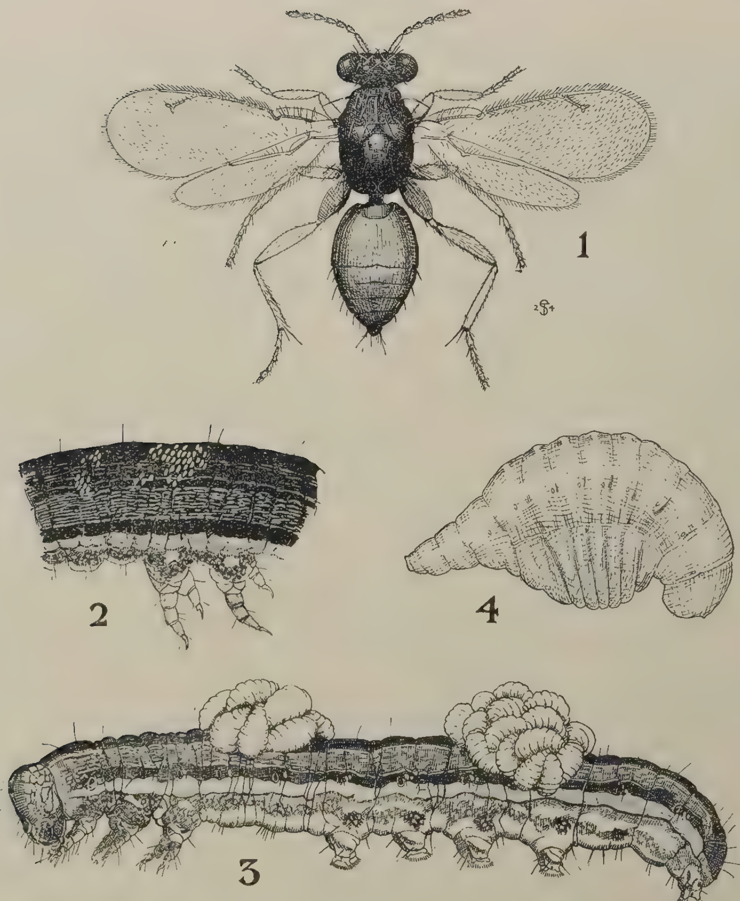
ILLUSTRATIONS APPEARING ON THE COVERS OF VOLUME XXVIII

No. 1

Here we have a comparison of the effect of an intensive application of water against a more extensive use over wide areas. Cooperative experiments at Waimanalo are now dealing with the problem of the most economical distribution of water. In connection with this work, cane measurements are made throughout the crop to show the interrelation between growth and the amount of irrigation at different seasons of the year.

No. 2



EUPLECTRUS PLATYHYPENAE

A Mexican armyworm parasite which has been introduced and widely distributed in an effort to control armyworms.

No. 3

The temperature and daylight from January to June is here registered in cane growth, each cutting representing that portion of a stalk that was produced during the month indicated below it.